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SLIT-LAMP MICROSCOPY OF THE LIVING EYE

SLIT-LAMP MICROSCOPY OF THE LIVING EYE

Early Diagnosis and Symptomatology of Affections of the Anterior Segment of the Eye

"Rien de ce qui est exact ne saurait être inutile.
Si petit que soit un phénomène observé, il porte toujours avec lui un enseignement profitable."—CUIGNET.

BY

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(Basle)

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INTRODUCTION

It is not without some hesitation that I have decided to publish this *Summary of Microscopy of the Living Eye.*

We have here a branch full of promise, but still very young. It may appear bold to condense, at this moment, the knowledge acquired, the more so as on certain subjects irreconcilable opinions have been expressed. To set forth all the appearances observed may be fastidious, to make a final selection would be dangerous. What has urged me to write this work is not so much six years' assiduous practice with the slit-lamp as the desire to be useful to French-speaking ophthalmologists, to whom the original works, almost all in German, are hardly accessible, and also the inestimable advantage of having enjoyed for several years the instruction of A. Vogt, indisputably the greatest master of the subject.

The terminology employed may appear formidable to the uninitiated. Yet he should be willing to take into account that he is often dealing with new conceptions to which it is also necessary to apply new terms, and that these have not been chosen without good reason.

The illustration was also a delicate point. I have tried to explain the essential facts by diagrams. In some cases I have been able to bring to my aid the impartiality of the camera. With a few exceptions, I have myself executed all the illustrations ; hence their imperfection.

The reader will meet more names of authors in this *Summary* than he is accustomed to find in works of the kind. In microscopy on the living, where the interpretation of images is often difficult and a personal factor plays a part, it is necessary to render unto Cæsar that which is Cæsar's. . . . I wished this *Summary* to be a faithful account of actual observations, and I have only set down, without reference, what I have been in

a position to verify with my own eyes. On the other hand, the bibliographical references will enable any one anxious for complete knowledge to obtain it.

The bibliographical index contains all the works which treat of the slit-lamp and the microscope, or of one only of these apparatus. Some may have escaped me. I hasten to ask their authors' pardon. By force of circumstances, the really " original " works are for the most part by German and Swiss authors.

I have laid stress on the methods of examination, which are of fundamental importance, and more especially on the phenomena of reflection of light, which so often lead to error. It may be thought, perhaps, that congenital anomalies and senile modifications have been over-elaborated. But the beginner may thereby be prevented from mistaking them for pathological changes, a mistake which easily happens. Broadly speaking, my purpose has been to throw into relief *early symptoms of eye affections* rather than to give a minute and exhaustive description of advanced stages. If I have also dwelt upon certain points, such as pigmentation of the cornea, the structure of the lens and vitreous, thermal currents of the anterior chamber, etc., it is because French treatises, even recent ones, almost, if not completely, ignore them.

For the sake of simplicity, the same method of arrangement has been adopted in each chapter : special technique of examination of the organ to be considered, normal appearance, congenital anomalies, senile modifications, traumatic lesions, pathological changes. I must confess that often purely didactic reasons have prevailed in the classification, and that such a subject, for example, as marginal distrophy of the cornea might just as well have been treated under pathological changes as under senile modifications, etc.

It need hardly be said that this work will only make profitable reading to those already *au courant* with ordinary ophthalmology, and that it will not supplant any of the excellent handbooks of ophthalmology in which French literature is so rich. Neither does my *Summary* replace Vogt's fine *Atlas*, but rather

condenses and completes it. I cannot even claim, in the popular phrase, to " fill a gap " (though a gap seems certainly to exist), but only *to show the beginner in ocular microscopy something of what is, and also to prevent him from seeing that which is not.*

F. ED. KOBY.

Holbeinstrasse,
Basle.

TRANSLATORS' PREFACE

This translation was undertaken to provide the English reader with a textbook which would also be a *vade mecum* for those who wish to become acquainted with microscopy of the living eye.

There are few textbooks on the subject in any language, and in none has the author set out so clearly the methods of use and fields of application of the slit lamp.

We have been careful to follow Dr. Koby as literally as possible, especially in dealing with new terms that have necessarily to be chosen for new conceptions. This is most important, since a reader, consulting papers in a foreign language, must be able readily to recognise synonymous terms. We give here, with their French and English equivalents, a list of the chief German terms which have been adopted by pioneers of the subject in connection with slit-lamp microscopy:

Krause.	Collerette.	Collarette.
Pigmentsaum.	Liséré pigmentaire.	Pigment border.
Betauung.	Buée.	Bedewing.
Schiller.	Chatoie.	Lustre.
Spiegelbezirk.	Zone miroitante.	Zone of specular reflection.
Durchleuchtung.	Diaphonoscopie.	Transillumination.
	Calque.	Reduplication.

We have both had the privilege of working under Dr. Koby, and have also enjoyed his co-operation throughout the translation.

Charles Goulden.
Clara Lomas Harris.

London.

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SLIT-LAMP MICROSCOPY OF THE LIVING EYE

CHAPTER I

APPARATUS

The apparatus consists essentially of a Czapski binocular microscope with an erect image, and a special lamp, called " the slit-lamp," the first model of which was presented by Gullstrand at the Congress of Heidelberg of 1911.

Let us now shortly describe these two apparatus.

THE MICROSCOPE

The microscope is binocular. The two oculars may be removed separately. The two objectives are fixed on the same mount, a metal plate of 21 by 51·5 mm. They converge at an angle of 14° towards the eye examined.

There are three kinds of objectives : F55, *a* 2, *a* 3, having as their respective lengths 20, 50 and 62 mm., and as focal distances 55, 37 and 28 mm.

As oculars we usually use Nos. 2, 4 and 6. The tubes in which the oculars are placed are movable and may be adapted to an inter-pupillary width of 54 to 74 mm.

A system of Porro prisms (with four reflections) allows us to obtain erect images.

The microscope is mounted on a sagittal slide allowing it to be displaced 35 mm. in depth. This movement is brought about by twin milled screws. Directly under these is found a joint with a transverse axis, by means of which the microscope may be rocked forwards and backwards.

To one of the screws may be adapted *Ulbrich's drum*, which

allows us to determine with fair accuracy the angle formed between the arm of the lamp and the direction of the microscope.

From the mechanical point of view the complete microscope *possesses five degrees of movement :* three rectilinear movements and two movements of rotation. The rectilinear are allowed by the two perpendicular slides (sagittal and frontal), and by the elevating screw (vertical), the rotations by the hinge under the microscope (fronto-horizontal axis) and by the foot, permitting rotation around a vertical axis.

Henker has devised a combination of the large ophthalmoscope of Gullstrand with the binocular microscope, a combination which he calls the " simplified ophthalmoscope." We do not know up to what point this combination has proved fruitful. A parallactic refractometer may also be mounted on the vertical support.

THE SLIT-LAMP

The slit-lamp is mounted on the horizontal arm of Henker, which is itself fixed on a vertical pivot to the elevating movement. The vertical support rests on a cast-iron arm, composed of two articulated segments, of which the greater is attached to the foot of the table around which it is able to turn easily. This method of fixation, although massive, gives a great mobility to the lamp, which is able to be moved to the left or right of the observer at any distance from the observed eye.

A hinge articulation may be interposed upon the vertical pivot, under the lamp. It allows us, if necessary, to illuminate the eye of the patient from above. It has the disadvantage that it raises the lamp too high. We do not recommend it.

Composition of the Gullstrand Lamp

The lamp is essentially composed of four elements :—

(*a*) The luminous body.
(*b*) The condenser.
(*c*) The slit.
(*d*) The illuminating lens.

(*a*) Originally the *luminous body* was a vertical Nernst filament about 2 cm. in length. Its light was white and homogeneous. We actually employ another lamp, as the Nernst is no longer made. The Nernst filament has the disadvantage of being very fragile. To become a conductor, the filament has to be raised to a certain temperature by a special arrangement, causing an appreciable loss of time.

The new *Nitra* lamp is more manageable and less expensive. The tungsten filament is wound vertically, like twist tobacco, in an atmosphere of nitrogen. Its temperature is raised, according to Koeppe, to 2,100° C., which gives it a great brilliance. It only uses one half-watt per candle. The actual model gives fifty candles.

On account of the twisted filament the luminous area in this lamp is less homogeneous than that of Nernst. Its light is more subject to decomposition. We shall see later how we may overcome these inconveniences. The Nitra lamp may be fixed very well on to an alternating current. It is necessary to interpose a rheostat reducing the tension to 8 volts.

By slightly overloading the lamp, from 1 to 3 volts, we obtain a much more considerable intensity. But the lamp naturally wears out more quickly.

We may obtain a still greater intensity of light by using an arc lamp, especially to be recommended for examining the vitreous. Several models are very useful ; they may be used in the ordinary way for *red-free* ophthalmoscopy, which requires a luminous source of great intensity which only the electric arc can furnish. But the practitioner may leave on one side the arc lamp, which is, of course, heavier and more cumbersome than the Nitra lamp, and which emits an appreciable amount of heat. We describe the Birkhaüser-Streit model later on.

(*b*) The *condenser* is composed of two plano-convex lenses of about 22 dioptres, the curved surfaces of which face each other. They are placed in such a way that the principal focus of the first coincides with the situation of the luminous filament and the focus image of the second with that of the slit. This arrangement is that of the original lamp of Gullstrand.

(*c*) The *slit*, properly so called, is a diaphragm 10 mm. in height. It may be rendered more or less wide by means of a screw. Its maximum width is 2 mm. For arc lamps we have to use special diaphragms.

(*d*) The *illuminating lens* usually has a spherical surface turned towards the eye to be examined, and of a refraction of 3·5 dioptres. The other surface is *aspherical*, corresponding to about 11 dioptres. We note that here the more curved surface is turned towards the luminous body, whereas it is the opposite with the first lens of the condenser. In this case the source of light is situated at the principal focus of the lens, whereas for the illuminating lens it is considered as if it were at infinity. This arrangement of lenses has the result, the reasons of which we leave on one side, of lessening spherical aberration.

Fig. 1.—Photograph of a lens of 7 cm. focal length. Projection of rays by the method of Vogt. The image of the filament is formed on the diaphragm of the lens.

The lens described has the disadvantage that it is very large, and may easily enter into collision with the microscope, especially when examining the vitreous body. The models in use are flattened laterally. The ophthalmoscopic aspherical lens of Zeiss usually has a stop of 16/45 mm. It is not corrected for chromatic aberration. Its focal length is 70 mm.

The lens of 7 cm. focal length furnishes a very luminous and narrow beam which allows rapid focussing. For these reasons it is preferable to that of 10 cm. The 10 cm. lens may be

advantageous for the examination simultaneously of several surfaces of discontinuity of the lens. It also allows us to examine the second eye by illuminating it *across the nose*, by leaving the lamp in its first position. So as to combine the advantages of the two lenses, we have had made a concave lens of 4 dioptres which may be adjusted in a moment to the 7 cm. lens of Vogt, giving it a focal length of about 10 cm. (Made by the Optical and Mechanical Works, Ltd., Basle.)

It is not necessary to use an aspherical lens. That of Vogt, which is not aspherical, but more strongly diaphragmed (11/16 mm.), answers the same purpose. It is also considerably less expensive. Its focal length is 70 or 100 mm. (*cf.* Fig. 1).

The elements *a* to *d* are mounted on a movable arm, at the extremity of which the illuminating lens may be moved backwards and forwards over a distance of 5 cm. by the use of a milled screw.

A blackened tube (of Koeppe) is placed between the slit and the illuminating lens and absorbs scattered rays which might annoy patient and observer. This tube may be furnished with a disc, absolutely useless, carrying glasses of various colours.

Path of the Luminous Rays

The principle of the lamp is to cause the illuminating lens to project not the rays emitted by the luminous body itself, the Nernst or tungsten filament, *but those which emanate from an image of this body.*

The Arrangement of Gullstrand.—The rays emitted by the filament, which is found at the principal focus of the first lens of the condenser, are projected in a parallel direction, after refraction, on to the second lens. This makes them converge to the second focus, which coincides with the slit. We shall have then, in the slit, a real and inverted image of the filament, which illuminates it entirely and uniformly. The illuminating lens then collects a portion of the rays emanating from this image and produces a second sharp and luminous image which

it is easy to project upon this or that part of the eye which we wish to examine.

We shall see later what is the form of the luminous beam projected by the illuminating lens. It is almost unnecessary to mention that, from the practical point of view, this beam alone interests us.

This method of projection has been shown to be inadequate with the Nitra lamp.

The Arrangement of Vogt.—A new arrangement has been devised by Vogt, and described by Swiss authors. It consists in bringing the luminous body closer to the condenser until the image, progressively removed from the slit, comes to be formed on the surface of the illuminating lens (*cf.* Fig. 1). The slit here only plays the part of a diaphragm cutting off the peripheral rays. In the focal part of the beam there is only a clear and uniform field without an image of the filament.

This method of projection is applied also with success to the arc lamp.

Recent models of the slit-lamp allow one to pass in a moment from the method of Gullstrand to the method of Vogt.

Optical Properties of the Luminous Beam

The bundle of rays emitted by the illuminating lens has the form of a pyramid, the base of which coincides with the diaphragm of the lens. After their crossing, the rays produce, naturally, a second reversed pyramid, the two figures touching each other by their apices. We may neglect this second pyramid.

The edges of the first pyramid, especially if we use an aspherical lens, or a small opening, may be considered as straight lines.

The luminous beam presents for study :—

(*a*) Its length (height of the pyramid).
(*b*) Its vertical height.
(*c*) Its width.
(*d*) Its intensity.
(*e*) Its homogeneity.

(*a*) Its *length* depends upon the focal length of the illuminating lens and its distance from the luminous slit. The focal length

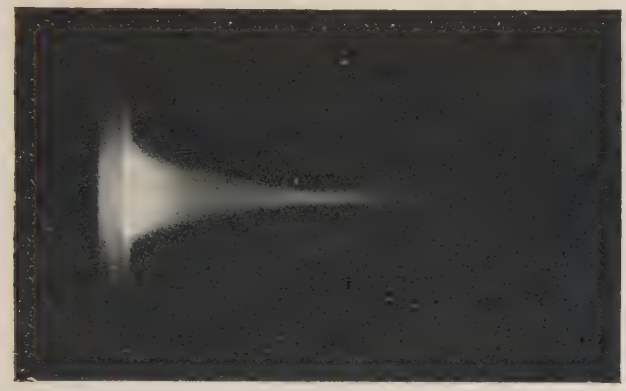

FIG. 2.—Extremity of the luminous beam. Method of Gullstrand. Aspherical lens of 70 mm. focal length. Nitra lamp.

most used being 7 cm. and the distance of the slit about 35 cm., the length of the beam measures an average of 8 to 9 cm.

FIG. 3.—Extremity of the luminous beam. Method of Vogt. Aspherical lens of 70 mm. focal length. Nitra lamp.

Lenses of greater focal length give a beam of greater length, and may present certain advantages in the examination of zones of discontinuity of the lens, or the vitreous body. Above 10 cm.

focal length the focal part is less well delimited, so that 10 cm. is a maximum that should not be passed. The beam of a lens of 7 cm. presents one advantage ; being more narrowed, its focus is more visible than that of a lens of 10 cm. Besides, as we shall see later, the focal part is considerably more luminous with a lens of 7 cm. than with that of 10 cm.

(*b*) The *height of the beam* depends, at its base, on that of the diaphragm of the lens. With the diaphragmed lens of Vogt it is considerably smaller than with the aspherical lens (*cf.* Figs. 2 and 6). The height of the beam in its focal part varies considerably with the method of projection of the rays. With the method of Gullstrand, the beam is less high in its focal part than with the method of Vogt, as the photographs (Figs. 4 and 5) show. In the method of Vogt the height is almost twice as great as with the other arrangement. The focal length of the lens also plays a part. The greater it is the greater the height of the beam in its focal part.

(*c*) At its base the *width* of the beam depends upon that of the diaphragm. Also, it is less with the lens of Vogt, with a stop of 11/16 mm., than with the aspherical lens, the width of whose diaphragm is 16 mm.

As to the width of the focal part, it depends directly, in the Vogt method of projection, on the width of the slit. The more the slit is narrowed the more the beam is narrowed laterally. In Fig. 5 it corresponds to a medium diaphragm of 1 mm. As the magnification is about twenty-five times, the real width is pretty nearly 0·2 mm.

By narrowing the slit still more we are able to produce *optical sections* of 50 microns thickness.

In the method of Gullstrand the primary image of the filament (Nitra) does not fill the slit completely. By diminishing the width of the slit we only cut off a few of the luminous rays and, as the intense part of the beam at its focus is chiefly composed of the second image of the filament, its width varies in a less appreciable way. For Fig. 4 a slit of 1 mm. also was used.

We shall see again that the limits of the beam, most important

in the focal part, are less sharp in the method of Gullstrand than in that of Vogt.

(*d*) The *luminous intensity* varies little for the same lamp, according to the method of projecting the rays. Vogt estimates that the beam, in his method of projection, is one and a half times more luminous than in the older method. The photographs (Figs. 4 and 5) have been made under the same conditions, same time of exposure and of development, same treatment of the print. Judging by these the total photochemical intensity of the rays is not very different in the two methods of projection.

This inquiry, already published by us in the *Archives d'ophtalmologie*, in 1922, has subsequently been confirmed by the theoretical deductions of Hartinger.

The following figures are published by Vogt :—

Brilliance of the luminous beam of the Nernst lamp .	Method of Gullstrand	1
Brilliance of the Nitra beam .	Method of Gullstrand	2·4
Brilliance of the Nitra beam	Method of Vogt .	3·3
Brilliance of the arc lamp .	Method of Gullstrand	24

These figures have been obtained by direct comparison between two slit-lamps differently equipped.

Hartinger has measured by photometry the specific luminosity of the primary images of Nernst, Nitra, Pointolite, and arc lamps, and has found, using throughout the same optical apparatus :—

	Volts.	Amps.	Candles/cm².
Nernst . .	110	0·48	230
Pointolite . .	35	0·6	269
Nitra . . .	10	3·9	1,335
Arc . . .	58	3·4	11,550

The same author has also calculated, setting out the table below, the brilliance of the focal part of the beam of different lamps, using lenses of 10 or 7 cm. focal length :—

	Lens of 7 cm.	Lens of 10 cm.
Nernst . . .	48,000 lux.	18,800 lux.
Pointolite . . .	56,300 ,,	22,000 ,,
Nitra (10 v.) . .	279,000 ,,	109,000 ,,
Arc	2,417,000 ,,	945,000 ,,

We see that the focal part of the beam of the 7 cm. lens is much more luminous than that of the 10 cm. lens. For this reason we prefer the first to the second.

(*e*) The *homogeneity* of the beam is as important as its intensity. It is clear that a white light, not giving any colours, will be more useful for judging the colour of that part of the eye examined or for seeing sharply certain phenomena, such as lustre of the surfaces of the lens in the zone of specular reflection.

The lamp being mounted according to the method of Gullstrand, let us move backwards and forwards in front of the lens a piece of white paper. We obtain near to the lens a white rectangular field, the borders of which are coloured red. Further from the focus the edges are tinted blue. At the focus itself the field increases considerably in intensity, and it appears homogeneous to the naked eye. But by looking at the screen with a sufficient magnification (obj., *a* 2 ; *oc.*, 2) we perceive that the beam is badly delimited, the central portion being more luminous than the periphery. Under certain special conditions one is able to see the image of the filament appear, showing the characteristic spirals (Fig. 4). For this it is enough to project the filament on to a surface which is smooth, but not bright, absorbing the light a little, such as the gelatine of a photographic plate, at a spot where there is a dense deposit of silver. For the photographs 4 and 5 we used a plate of glass covered with a thin layer of lamp black.

It is quite different in the method of Vogt. The screen held between the focus and the lens will show a less homogeneous field in which the filament is figured more or less sharply, and considerably enlarged. Beyond the focus an image is also obtained which is larger the further the screen is withdrawn. But in the focal part the screen gives a field of rectangular form, perfectly homogeneous, with sharp borders (Fig. 5). *Ceteris paribus*, the height of the rectangle remains constant,

FIG. 4.—Focal part of the luminous beam projected on to a smooth and sufficiently black surface. Method of Gullstrand. Lens of Vogt of 70 mm. focal length. Nitra lamp. Obj. *a* 2, *oc.* 2.

FIG. 5.—Focal part of the luminous beam projected on to a smooth black surface. Method of Vogt. Lens of Vogt of 70 mm. focal length. Nitra lamp. Obj. *a* 2, *oc.* 2.

but the width, as we have seen above, varies directly with the width of the slit. With a slit of 1 mm., the height measures ten times the width. This proportion is to be recommended for routine examination.

The Astigmatic Beam of the Author.—To obtain this beam a plano-cylindrical glass of 9 dioptres, with horizontal axis (made by The Optical and Mechanical Works, Basle), is put into the mouth of Koeppe's tube, which should be turned towards the illuminating lens. With the lamp mounted according to the method of Vogt, it is seen that the image of

the filament is considerably shortened and condensed, and that whereas previously only five turns of the spiral were utilised by the lens, now seventeen turns pass through the diaphragm. *The intensity of the beam then becomes three times as strong.* As, in the position of the old focus (*distal* focus), the height of the beam is three times as great, the *specific* intensity does not change. But the height being then 12 mm. if the 7-cm. lens is used, the whole section of the cornea and lens may thus be examined at a single glance. At the *proximal focus* of the beam, situated between the distal focus and the illuminating lens, the section of the beam is not changed in form, but its luminous intensity is three times as great, and, a very appreciable advantage, the design of the filament has disappeared, and *the light is practically homogeneous.* The whole of the beam between the two foci is suitable for examination. (*Cf.* the author : " Une modification à la lampe à fente ; utilisation d'un faisceau lumineux astigmatique," *Rev. gen. d'opht.*, 1925.)

The astigmatic beam combines, therefore, the advantages of the method of Gullstrand and Vogt, while having a higher luminous intensity. The distal focus is suitable for all examinations by focal light (thickening, thinning, deformation of the cornea, etc.), the proximal focus for surface examination in homogeneous light (shagreen, iris, etc.). This arrangement is useless for high magnifications. The cylindrical glass can then be removed in a moment.

The Narrow Beam.—In the method of Vogt it is possible to narrow the slit considerably without the focal part of the beam losing its sharpness. The luminous intensity diminishes proportionally with the width of the slit, which can be reduced to one-fifth, or even one-tenth of a millimetre. In the latter case the intensity will be twenty times more feeble than with a maximal slit of 2 mm. ; but then we really obtain an *optical section of the tissues.* Diffraction of the light, which is theoretically to be feared, does not cause any appreciable trouble.

The Conical Beam.—By using a round hole in place of the rectangular slit, we see the beam lose its prismatic form and become *conical.* The screen shows us at the focus a luminous

circular field, slightly bordered with red or blue. Only the method of Vogt allows us to obtain a sharp figure with a minimum of decomposition of light. In the method of Gullstrand, the figure of the filament is easily seen, and it is noticed that only a part of it contributes to the formation of the beam. Also, the luminous intensity of the conical beam is naturally less than that of the prismatic.

Considered apart, the conical beam is sharper the smaller the stop. We obtain then a veritable *pencil*, very narrow, the focal part of which may be considered as *cylindrical*. It is with this adjective that Vogt describes it.

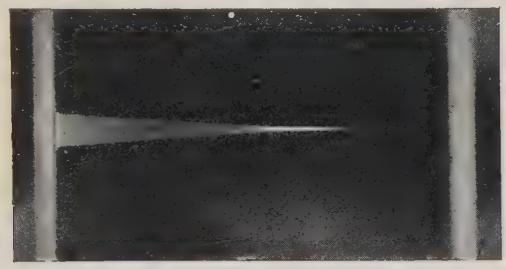

Fig. 6.—Extremity of the luminous beam obtained by using the hole of 1 mm. (conical beam). Method of Vogt. Lens of Vogt. Nitra lamp.

For Fig. 6 a hole of 1 mm. was used, the lens and method of Vogt. We notice in the figure clear striæ alternating with dark bands. Each clear stria corresponds to a spiral of the filament with its convexity turned towards the lens. This striation is only well marked if the lens is sufficiently stopped down. It also occurs in front of the illuminating lens, as we may see by puffing some smoke into the path of the rays.

Adjustment of the Lamp

It is easy, in recent models of the slit-lamp, to pass from one method of projection to the other. If the lamp is mounted in the method of Gullstrand and it is desired to pass to the method of Vogt, we first unscrew the first screw on the left, the nearest to the switch. We thus free the two metal sleeves which contain the

lamp, and can slide one on the other over a distance of several centimetres. We then place the illuminating lens in the middle of its range of movement and hold a screen in contact with it. The lamp being lit, we push it forward until the image of the filament is figured on the screen. At this moment it is in focus (*cf.* Fig. 1). We fix it at this spot by moderately tighten-

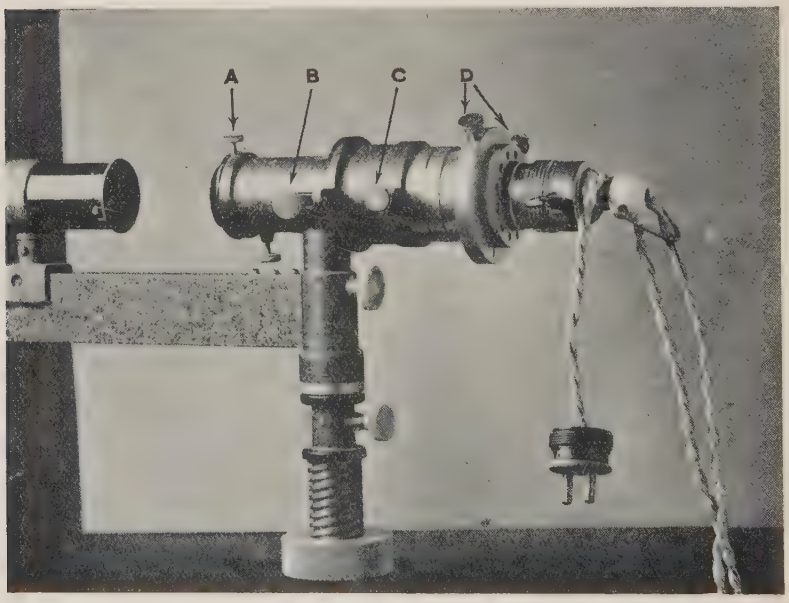

Fig. 7.—Nitra slit-lamp. Original model of Zeiss. A, Screw governing the width of the slit. B, Screw displacing the condenser laterally. C, Screw fixing the metal sleeves. D, Twin screws moving the bulb.

ing the screw. The screw which displaces the condenser laterally, as well as those which modify the position of the bulb, ought to be regulated exactly once and for all.

On the other hand, if we wish to return to the method of Gullstrand, we draw the lamp backwards, after having freed it, until the moment when a screen held 10 cm. from the slit shows a luminous field of oval form. We shall notice that, with the method of Gullstrand, a great amount of light

passes by the side of the illuminating lens, worrying both patient and observer.

During these manœuvres, which only take a few seconds, care must be taken to keep the filament strictly vertical. With a little practice it is soon possible to dispense with the screen.

As to the conical beam, this is obtained instantly by turning the disc placed in front of the slit, and which carries a rectangular diaphragm of 3 mm. in width, with rounded corners and two round holes, the larger of which, of 1 mm. diameter, is enough for all purposes. If one of these holes is used, it is necessary to enlarge the slit sufficiently, otherwise the conical beam will be flattened laterally.

Application of the Principles explained above to Clinical Examination

If we wish to examine a globe with low magnification (obj. F55, oc. 2) we must arrange a diffuse illumination over a large surface. We will have recourse to a beam projected according to the method of Gullstrand, which furnishes a field illuminated in a homogeneous fashion. It is better still to use the astigmatic beam, which, at the proximal focus, gives a homogeneous and more luminous section. In other cases, the distal focus will be used.

Thus, what is demanded of the microscope, furnished with the slit-lamp, is not only to be able to see with a higher magnification those things which were already visible with the loupe, but to create new optical conditions. The classical studies of Vogt on the lens have shown that it is composed not only of a nucleus and a cortex, but of a certain number of layers separated by *zones of optical discontinuity* that only a localised illumination could put in relief. In the examination of the cornea, if it is wished to distinguish the anterior surface from the posterior, it is necessary to narrow the beam. The prismatic beam cuts out in the cornea a bright rectangle (anterior surface, anterior *band*) covering more or less, according to the angles of incidence and of observation and the thickness of the cornea, a second rectangle less bright (posterior surface,

posterior *band*). If it is wished to examine the posterior surface, it is necessary to attain in the projection of the beam, a more oblique direction, that is to say, to increase its incidence, which causes the two rectangles to separate, but this end is more easily reached by using a narrower beam. In this same way, if it is desired to localise exactly a foreign body, etc., it will be necessary to use the *lateral faces* of the beam (*optical section*), which will have to be reduced to the utmost.

These conditions : *homogeneity, sharp delimitation, and easy narrowing of the beam are obtained only by the projection of the rays by the method of Vogt, which will therefore be the method of choice.*

The conical beam has very limited applications. It will be useful, for example, in determining at what depth a point is situated, or to verify if at some spot the anterior chamber is partially conserved or completely obliterated.

The narrow beam lends itself especially for discriminating the zones of discontinuity of the lens and of the cornea, for investigating the " bands of disjunction " of the lens, etc., or for localising any lesion whatever in the interior of the lens or of the cornea.

A broad beam is much more useful for general views, the examination of the " shagreen " of the surfaces of the lens, the " relief " of the adult nucleus, etc. As we have seen above, if we wish to use also the prefocal portion of the beam to increase further the illuminated field, we will bring to our aid the method of Gullstrand, or, better still, the astigmatic beam (proximal focus).

The routine arrangement advised for the practitioner will be : Nitra lamp, projection of rays by the method of Vogt, slit of 1 mm. As to magnifications, objectives *a* 2 and oculars 2, give a magnification of 23, which will be sufficient for all cases.

Appendix

Arc Lamps.—What we have already said of arc lamps excuses us from discussing this subject at any length. Several models have been designed (Vogt, Schnyder, etc.). We will describe

shortly here that of Birkhaüser-Streit, because it presents certain advantageous arrangements.

The Birkhaüser-Streit lamp has some original features. It is mounted on rollers in such a way that it may be moved forwards or backwards *sagittally* in relation to the part examined,

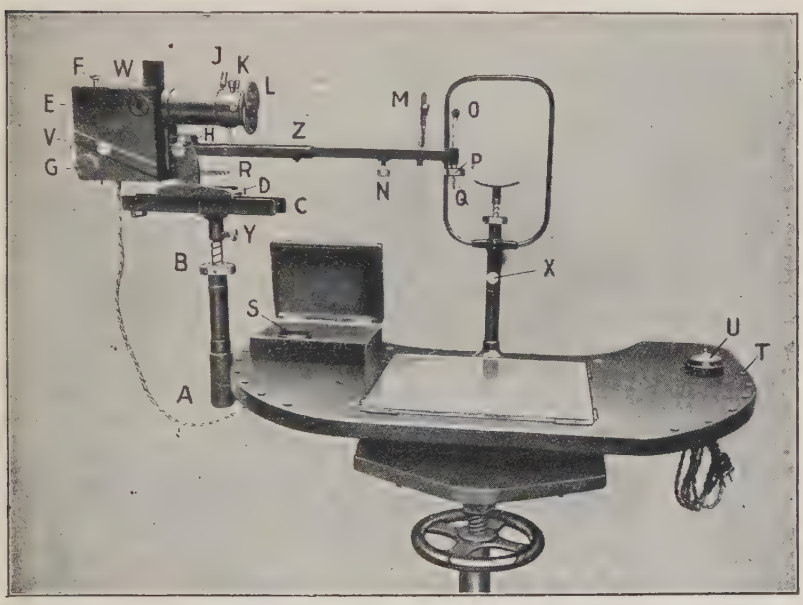

Fig. 8.—Birkhaüser arc lamp (maker: A. Streit, Berne). This model unites the high luminosity of the electric arc to the principle of the slit-lamp. The table is spacious, with rounded corners, and carries marks (T), indicating the incidence of the luminous beam. The lamp slides sagittally on a slide C. The arm Z possesses a movement which can be regulated. The lens M and the mirror O are of special design, likewise the chin rest and head rest. The axis of rotation of the long arm of the lamp will be found under the chin rest.

which is not accurately possible with the Zeiss model (arc or Nitra lamp). This arrangement certainly facilitates the focussing of the beam. In front of the illuminating lens, which is the aspherical achromatic model, is placed a small metallic mirror, which may easily be lowered and which renders good service in examining the vitreous, by allowing the transmission of rays under a very much reduced angle of incidence. The

centre of rotation of the long arm of the lamp is no longer at the foot of the table, but at the support of the chin rest, which saves the observer the movement of drawing back necessary to change the lamp from right to left, or *vice versâ*.

The head rest and chin rest are of special shape. Finally, an ingenious diaphragm gives to the beam a special rectangular section with two vertical prolongations, making it easier to localise any point at a depth.

The lamp may instantaneously be transformed into a source of *red-free* light.

The latest model of arc lamp made by Zeiss, lighter and more manageable, may also be used for ophthalmoscopy with red-free light.

Micro-photography.—It would be a desirable thing to be able to record photographically many microscopic appearances. But the problem presents difficulties that would appear insoluble. Photography of the fundus of the eye, in spite of the application of eminent investigators, has not yet given much practical result. It is, however, much more easy than that of the endothelium of the cornea, for instance.

We might obtain, with the arc lamp, images sufficiently luminous, but it is extremely difficult to focus them, and, further, their own luminosity varies within wide limits. The human eye adapts itself to different luminosities much better than the photographic plate, and is able to see clearly an object much darker than surroundings which are bright enough to fog a plate. Again, if we succeed in obtaining sharp photographs, they will only give one plane, and tell us nothing, for example, about the localisation in depth. We shall see later that, above all, *the examination should be made kinematically*, that is to say, that by co-ordinated displacements of the beam and of the microscope, we ought to examine the media section by section and layer by layer.

Three apparatus, all stereoscopic, have been suggested for photography of the living eye.

Drüner used either an objective of F = 55 mm., or a *tessar* of F = 150 mm. The magnification varies from one to four

times. He recommends subsequent enlargement of the negative. By daylight, and in good conditions, we are able to work instantaneously with one-tenth of a second exposure.

Lœwenstein uses objectives F = 55 of the microscope, and as a source of light, an arc lamp. For an enlargement of one and a half times, an exposure of one-quarter of a second suffices, of five times, two seconds.

Lenz uses two *planars* of F = 75 mm., giving a magnification of one-and-a-half to three times. Focussing is facilitated by using the principle of the camera lucida. The shutter is fixed on the tube of the arc lamp which furnishes the light. The time of exposure varies from one-fifth to several seconds.

All these apparatus attack with more or less success the problem of increasing the depth of field without lengthening the time of exposure. It is possible, under good conditions, to obtain satisfactory plates, but the *magnification of the images is very small, and the principle of illumination by means of a slit entirely sacrificed.*

We have ourselves obtained, but only with enucleated eyes, passable plates, with an over-loaded slit-lamp and a photographic camera fixed in the position of one of the oculars of the microscope and giving a magnification of about 25 (*cf.* Fig. 12).

Microscopic Examination of the Fundus of the Eye with Focal Light.—Koeppe has invented a method which allows an examination of the fundus of the eye with a high magnification by focal light. For this a special microscope is necessary (*bitumi*, which gives inverted images, or *orthobitumi*, which gives erect images), a silvered mirror to give to the beam a maximal incidence, a contact glass to apply to the cornea, and above all, a very willing subject with patience for any ordeal. An identical method allows the examination of the angle of the anterior chamber. The apparatus is very complicated and costly. The bitumi, by reversing the relief, also sacrifices the usual stereoscopic vision. In the orthobitumi, the image is considerably brighter in one ocular than in the other, which may compromise binocular vision. A maximal dilatation of the pupil is necessary for the examination of the fundus of the

eye ; for gonioscopy, an instillation of eserine is necessary. For these many reasons, and others as well, however interesting they may be from the theoretical point of view, and however meritorious the ingenuity of researchers, it is anticipated that these methods will never be used in current practice. Also let us have the courage to admit that the clinical benefit that we have obtained up to now has remained so very modest.

We record here the praiseworthy researches of Valois and Lemoine, who have striven to do away with contact glasses, and who use the ordinary microscope. Unfortunately, they have only reached their ends by abandoning the advantages of focal light.

Other Models of Slit-lamps.—The description of the apparatus which we have given above applies to the latest Zeiss models. Other manufacturers have brought out slit-lamps.

Bausch and Lomb Model.—The microscope is almost the same as the Czapski-Zeiss. The slit-lamp is mounted on a central vertical support, and it is the microscope which, hinged to the support, pivots around it and is able to be moved to the left or to the right. The lamp is lit by a bulb similar to the Nitra. The image of the filament is formed on the illuminating lens. There are two illuminating lenses, one of 7 cm. focal length, the other of 10 cm., which may be quickly exchanged. Two diaphragms of unequal opening may be employed indifferently with the two lenses. We have had no experience with this apparatus and reserve our judgment.

The Stenopæic lamp of Valois (Gambs' model) may be altered into a slit-lamp and applied to the microscopy of the living, at least to low magnification.

Model of Fincham.—Fincham in 1924 devised a slit-lamp with certain peculiarities. The lamp (12 volts, 24 watts) has a straight filament. The condenser, composed of a convex and concave lens, projects parallel rays, in the path of which a diaphragm, either in the form of a slit or a tiny hole (stenopæic), is placed. A compound lens (couplet) of 5 cm. focal length is used as an illuminating lens. The microscope, simple in form, is monocular. It is yoked with the lamp by means of

a support in the form of the arc of a circle in such a way that its object focus coincides with the image focus of the illuminating lens. The microscope can be moved along the arc of a circle and the lamp pivoted about a vertical axis. The combined apparatus is very convenient for measuring the depth of the anterior chamber. As we have had no personal experience with the apparatus, we refrain from criticising an arrangement which seems to us to have few advantages.

CHAPTER II

METHODS OF EXAMINATION

A THOROUGH knowledge of the methods of examination by the slit-lamp is necessary to obtain all the help that it is able to render. A good technique also is as indispensable as for the ophthalmoscope, and with the microscope things are much more complicated.

To observe properly the details of structures and the alterations of tissues, it is necessary to realise two conditions :—

(*a*) *Focus the beam* exactly on the spot to be examined, which ought to be illuminated by the *focal part.*

In certain methods we shall see later that the focus of the beam should be *at the side* of the spot examined, or *behind* it, but it is necessary in all these cases to know exactly where to find the focus.

(*b*) *Focus the microscope* on this spot. Focussing the microscope presents no difficulty.

That of the beam is much more easy when the focal length of the lens is short.

An exact focussing of the beam and microscope is necessary for an examination. As in ophthalmoscopy by the indirect method (inverted image), the two hands of the observer must aim for the same end. But whereas in ophthalmoscopy the method of illumination does not vary much, in microscopy the methods of illumination are many.

METHODS OF ILLUMINATION

We have at command four methods of illumination :—

1. Direct illumination (oblique light, focal).
2. Examination by transillumination.
3. Examination in the zones of specular reflection.
4. Indirect illumination.

If, in certain cases, only one of these methods is indicated, in others we have the advantage of using several successively, which we realise by displacing the illuminating lens laterally. What Koeppe calls examination in the "field of oscillation" is nothing else than a combination of methods 1, 2 and 4.

1. Examination in **direct light** is the easiest. Lesions should be illuminated by the **focal,** the narrowest and brightest part of the beam.

The intensity of the beam is sufficiently great to allow us to see small opacities in the transparent media of the eye, which become specially visible if they stand out on a *dark background*, as in the ultra-microscope. This method of illumination is useful for all the anterior parts of the eye, and *it is this which we employ for the first localisation.*

In certain cases it is necessary to have a much larger field illuminated in a homogeneous manner. The lamp will be arranged advantageously according to the method of Gullstrand (formation of the image of the filament in the slit), which gives to the beam a homogeneous composition in both pre- and post-focal parts. In the method of Vogt we shall see the spirals of the filament figured with their chromatic decomposition.

An illumination of the surface is useful for the examination of the shagreen of the lens, and it is necessary for that of the spherules. It is also indicated when judging the shape of the pupil or the colour of the iris, etc.

2. In examination by **transillumination** we observe the lesions *by transparency in reflected light.*

For this examination a *reflecting screen* is necessary, which for the cornea is provided by the iris or lens, especially if it is cataractous, for the iris by the lens, for the anterior portion of the lens by the posterior. Naturally, the object examined must have a certain amount of translucency.

It should be noted that various objects appear under one colour by transillumination and another in oblique illumination. For example, vessels in the cornea which appear white in oblique light are reddish in reflected, etc.

We must also take into account the fact that reflected light

takes on the *tint peculiar to the reflecting screen*, a tint which we must not attribute to the object seen by transparency. Thus the bedewing of the endothelium or of the epithelium of the cornea, seen by transparency in the light reflected by a brown iris, appears brown.

Finally, certain bodies, seen by transparency, present a different colour, usually complementary, to that in direct illumination. Certain opacities of the lens, for example, appear blue or green in focal illumination and yellowish in reflected light.

Epithelial and endothelial bedewing is seen better by transillumination. These pathological phenomena must not be confused with the fine dew which normally exists in the epithelium, especially in the peripheral portion of the cornea, or with the fine layer of grease which floats on the epithelium of certain people, and which is probably produced by an excessive secretion of the Meibomian glands.

With the iris, the method of transillumination allows us to observe atrophy of the posterior retinal layer, the atrophic areas appearing clear on a dark background, and depigmentation of the pigment border, a senile phenomenon, or one following inflammation.

Bullæ, or vacuoles of the cornea or lens, appear to be bordered by a line which is usually black. In cataract, vacuoles may form a veritable carpet situated under the anterior capsule. Certain very thin opacities which appear white in focal light are often so diaphanous, when seen by transmitted light, as to take on the appearance of flattened droplets. (*Coronary* cataract of Vogt, *floriform* cataract of the author.)

Generally the light employed in transillumination is reflected in a very diffuse manner by deeper planes. It is then possible to examine the cornea, and more especially the anterior layers of the lens, by the light regularly reflected by the posterior capsule. So as to find this reflection, we focus the posterior zone of specular reflection of the lens, and, keeping the axis of the microscope in the plane of regular reflection, we withdraw the instrument little by little. The image of the filament,

diaphragmed by the illuminating lens, is formed near to the anterior capsule. It is analogous to that of Fig. 15, but not of the same origin. By withdrawing the microscope still more, we shall come upon the cornea in focus.

The catoptric image of the filament which the posterior capsule produces is obviously much smaller than that produced by the cornea, and less luminous. These points will be of use in distinguishing one from the other.

The use of the reflex of the posterior capsule has only a limited application and is not very easy, especially if the pupil is not dilated. Its great advantage is that it gives a white light. This method has been chiefly expounded in detail by Graves.

3. We shall see a little later what we mean by **zones of specular reflection** of portions of reflecting surfaces where reflection of light takes place. It is a *zone of discontinuity* that we focus, and *not an image.*

Although the zone of specular reflection may be rendered visible chiefly by light reflected slightly *irregularly*, the eye of the observer must be placed in the direction of rays reflected *regularly*, the angle of observation, formed by the microscope and the normal to the surface under consideration, being equal to the angle of incidence of the luminous beam. In other words, the angle which the luminous beam makes with the axis of the microscope ought to be divided into two equal parts by the direction of regard of the person examined, if the point observed happens to be near the optic axis.

Usually, sooner than displace the microscope, we ask the patient to look in a chosen direction and then give a wide incidence to the luminous beam.

In the zones of specular reflection we see chiefly *small inequalities of the surface* and certain details of tissues which would pass entirely unobserved. This method is indicated for examining the anterior and posterior *shagreen* of the lens, the *relief* of the adult nucleus, and chiefly for that of the *endothelium of the posterior surface of the cornea,* the cells of which are not rendered visible by any other means.

4. Examination by **indirect light** is practised by concentrating

the light *at the side* of the spot we wish to examine. As the light is diffused round the change we are examining, and *behind* it, it often really comes to an examination by transillumination.

This method of examination has only a few well-established uses. We will have recourse to it to make hæmorrhages into the iris stand out. The spot of hæmorrhage remains invisible in direct light, whereas it shows up brightly in red if the neighbouring stroma is illuminated. The presence of the sphincter of the iris and that of chromatophores in its stroma are also revealed in this way.

This method of illumination may be combined, with advantage, with that of direct illumination. It may be attained by giving to the illuminating lens oscillations proportional in size to the object we are examining.

It is also possible to examine the cornea, more especially the limbal portion, by projecting the light upon the neighbouring sclera (" sclerotic scatter " of Graves). If the incidence of the rays is sufficient, the whole of the cornea is faintly illuminated, as well as a part of the limbus immediately opposite. This is an example of the phenomenon of total reflection which we shall meet again later.

LOCALISATION IN DEPTH

Often, very often, it is of great importance, in ocular microscopy, to determine at what depth, in what layer of the membranes of the eye some alteration or other is situated. For this discrimination the usual methods of clinical examination, based chiefly on the displacement of two points of reference in the movements of the eye, are of no use.

We will have recourse to the four following methods :—

(*a*) **Focussing of the Microscope.**—The method of illumination most suitable here is by the light reflected from deep planes. How can we determine at what depth some opacity is situated in the lens ? In such a case we arrange the microscope perpendicularly to the layers containing the point in question and then focus exactly the anterior surface of the lens (by means of direct light) ; then we focus the spot to be localised. By the

greater or less displacement that the microscope suffers we judge approximately the distance of the point from the anterior surface of the lens. For a point situated nearer the posterior surface of the lens we first of all focus upon this. It is clear that during this manœuvre the globe must be absolutely still. The micrometer drum of Ulbrich (*vide supra*, p. 1) may be of great use here if we wish for comparative if not absolute values.

The method only gives good results if we possess a certain mastery in the employment of the apparatus. It is true that in such a case we use this method unconsciously all the time.

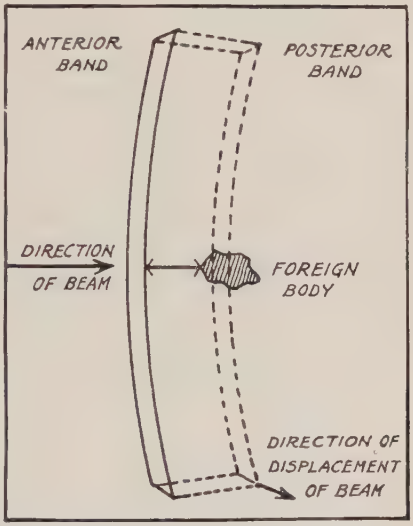

FIG. 9.—Diagram showing how a foreign body in the interior of the cornea is localised. The light comes from the left of the observer. The corneal parallelepiped is displaced towards the right by making the luminous beam move in the same direction. At a given moment, the optical section, the lateral surface to the right of the parallelepiped, is tangential to one extremity of the foreign body. The distance between the body and the right edge of the anterior band indicates its *relative depth* in the interior of the cornea.

(*b*) **Method of the Optical Section.** — None of the media of the eye are absolutely *empty* from the optical point of view, unless the anterior chamber in the normal condition may be considered practically so ; we recognise the prismatic form of the beam in the transparent media. The surfaces of discontinuity give rise to *bands*, more or less clear, situated normally to the direction of the luminous rays. We give the name *optical section* to the lateral surface of the beam turned towards the observer. The light coming from the left of the observer, the section will be the lateral face of the beam turned towards his right. Whatever may be the width of the

slit, the form of the section remains practically the same. On the other hand, *the more the slit is narrowed the more the bands are reduced in width if they are situated near the focal part of the beam.*

It is in the section of the beam that we judge of the depth of any lesion. As a matter of fact, we are able to judge its relative depth at the moment the point considered appears in the beam. If we are dealing with the cornea, for instance, we are able to say whether the point is situated in the outer third

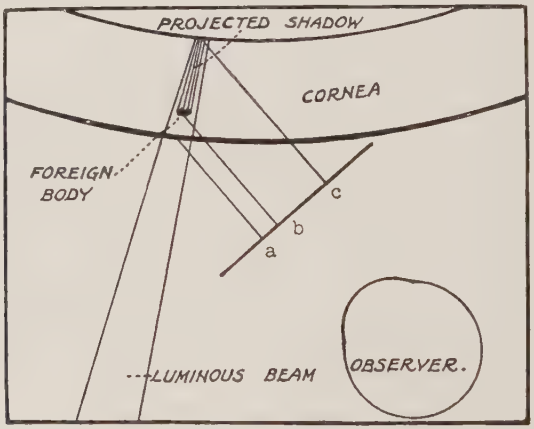

FIG. 10.—Diagram representing the shadow projected by an intra-corneal foreign body. Let the distance *ac* represent the apparent thickness of the cornea, *bc* the length of the projected shadow, and *ab* the depth of the body in the interior of the cornea. The point *a* is found by reducing the width of the beam.

of the thickness of the cornea, or in the middle third, etc. With the aid of a micrometer in the eyepiece we are able even to interpret these data in *relative values* (*cf.* Fig. 9).

It is clear that a point situated at the posterior surface will only appear in the posterior band, and nowhere else in the section.

It is, of course, necessary *to keep strictly to direct illumination*, because points situated between the section and the eye of the observer may be seen by transillumination, but cannot be localised as if they were in the section.

This method of localisation in depth is chiefly applicable to the cornea and lens. It is good enough to give us indications which are sufficiently exact for clinical work. It has allowed Vogt to make interesting observations on the growth of the lens that we shall meet again later on.

(*c*) In certain cases the **zones of specular reflection** may also give indication of the depth of some point. Thus an opacity situated behind a zone of specular reflection will obstruct no part of the reflection, as will be the case if it is placed in front of the zone. For example : after a parenchymatous keratitis, if we focus the endothelium, it will be crossed by sharp dark lines, vascular remains found *exactly* in front of it.

(*d*) *The length of* **shadows projected** *by an opaque body*, finally, sometimes furnishes information. Thus, for an intra-corneal body, if the beam strikes the cornea normally, the length of the projected shadow indicates the distance between the body and the posterior surface of the cornea. In a general way, this distance is equal to the length of the projected shadow divided by the sine of the angle of incidence (*cf.* Fig. 10).

We may, also, sometimes use catoptric images as points of reference, taking for example the image of the filament, diaphragmed by the illuminating lens (method of Vogt). The catoptric images formed by the surface of the cornea, and by the posterior surface of the lens, are sufficiently sharp to be of use in this manœuvre. But their situation varies according to the position of the illuminating lens and the convergence of the luminous rays. With a Vogt lens of 7 cm. focal length, for example, the images formed by the posterior capsule and the cornea are almost exactly at the same level, in the neighbourhood of the anterior capsule of the lens. The former has an apparent diameter of 0·7 mm., the second of 1 mm.

We have often observed that in myopic eyes the image formed by the cornea may be found quite clearly in the anterior chamber.

The use of catoptric images for localisation of depth has, so far, not been mentioned in microscopy of the living eye. They have chiefly a theoretical interest.

GENERAL TECHNIQUE OF EXAMINATION

The examination is carried out in a darkened room. However, it is not necessary that the darkness should be complete. It is better to retain a slight glimmer, which will allow the observer to find his way about. The apparatus will be arranged in such a way that this faint light comes from behind the observer, so that it does not incommode him, and allows him to superintend the position of the patient.

The microscope table will rest on a carpet or linoleum of small value, the weight of the table and the accessories being so great.

The head rest may be fixed to one of the short sides of the table, or to one of the long sides, the latter arrangement being more convenient.

The seat for the patient will be without back and of regulable height ; that of the observer may be fixed.

The rheostat will be fixed to the wall or upon the floor. In both cases, seeing the development of a considerable amount of heat, it should be mounted on an insulating plate.

The patient will rest his arms upon the table in a comfortable position which he will be able to maintain for a long time without fatigue. It is as well to make him fix his head before putting out the light. He will then be enjoined to press his forehead against the frame *throughout the examination.*

We will begin by bringing the microscope to the level of the eye. The axis of the objectives should remain horizontal. We then direct the microscope sagittally to the eye examined, and arrange it at a proper distance, taking into consideration the fact that, whatever the objective used may be, the distance of the base of the objectives from the eye remains constant. Having done that, we focus the beam upon the cornea, the lamp being to the temporal side as regards the patient, and it is only then that we focus the microscope definitely on a point by directing it on to the illuminated part.

The hand of the observer situated on the side of the lamp will remain on the pinion of the illuminating lens, ready to

interpose, while the other hand will manœuvre the sagittal slide by means of the large screw. If we wish to make the apparatus move in a frontal direction the hand which holds the screw of the sagittal slide will momentarily leave it for the other screw, and will immediately return to the former position.

It is not recommended to use, even momentarily, the hand which is occupied with the lens to manœuvre the microscope. By doing this, we run the risk of not again finding the pinion of the lens in the darkness without involuntarily displacing the arm of the lamp.

In the same way it is only exceptionally that we use the twin screws situated immediately beneath the microscope and which control its sagittal movement. If, however, the microscope is not mounted on slides, we shall have to use the screw more often.

These details have more importance than may appear. Only a good *co-ordination* of all the movements will allow us to make a rapid and precise examination.

It will be necessary to raise or lower the chin rest according to the height of the patient, *so that the eyes of different patients may always come to rest at the same height*, whereas the head rest ought to remain fixed once and for all, with rare exceptions.

At the outset we will use ocular No. 2, combined with objectives F55 or *a* 2. *Until he has mastered the foundations of the technique, the beginner should restrict himself to one magnification only.* Never attempt to obtain a sharper image by a higher magnification, but make certain that the technique is correct, and that corneal nebulæ, etc., have not escaped the first examination.

Also we ought never to examine a patient with a microscope without having proceeded to an investigation by the usual methods.

It is well to undergo an examination oneself, so as to judge of the dazzling that the examination provokes. This dazzling with the Nitra lamp is bearable, because the sensitive portions of the retina are struck only by divergent rays. There is no

reason for needlessly illuminating the patient. Immediately the eyes quit the eyepieces the beam should be removed from the globe. At the beginning of the examination we direct the beam into the pupil by a movement that should not be sudden. The intelligent patient will be grateful to us for these precautions. On his part, *the patient should not speak a word when the examination has begun, and should hold himself perfectly still.*

Are the images not sharp, or not well fused ?

The observer is anisometropic, or does not possess binocular vision. Let him be tested with the diploscope, or correct his error of refraction.

The eyepieces are not adapted to the pupillary distance. Correct them.

The mount of the objectives is not pushed home in the slide, or the eyepieces are not completely pushed into their tubes. Correct this.

Often, very often, the patient will not have pressed his head against the frame, or will have withdrawn it during the examination. Make him press his head against the frame.

The patient will have had an instillation of greasy drops, or possibly will have an insensitive cornea, on which desquamated cells and mucus have collected, or, finally, he will have very diffuse nebulæ. All these conditions should have been revealed by the preliminary examination.

PRACTICAL EXERCISES FOR THE BEGINNER

We cannot too often recommend the beginner to carry out practical exercises before confronting a patient. These will be principally exercises of focussing the beam and the microscope.

Pig's eyes, freshly enucleated, serve very well for these manœuvres.

But first we must learn to recognise the path of the luminous rays emitted by the lamp. Following the instructions given above (p. 7), we will project the rays according to the method of Gullstrand, and then of Vogt. Focussing the beam on a sheet of paper and examining the luminous patch with the

microscope, we learn to recognise its optical properties. We will also make use of a chamber with parallel transparent walls containing a solution of fluorescein, in which we will examine the shape of the beam.

Then we will practise exact focussing of the beam on the cornea of an enucleated eye, which we will first view under low magnification. By focussing the microscope still deeper, as well as the beam, we will throw into relief the structure of the lens, and if the animal to which it belonged was sufficiently old, we will clearly distinguish zones of discontinuity in which luminous *bands* stand out.

The shagreen of the lens may be seen in the rabbit, pig and ox. It appears at the edge of the pupil when the incidence of the luminous rays is sufficient.

The sutures of the lens are easily seen in domestic animals. So as to orientate enucleated eyes, we will use the following criteria : the lower side of the globe is indicated by the optic nerve, which is inserted obliquely from above downwards ; the nasal side is marked by the flattening of the end of the oval of the cornea, which takes the shape of a triangle on its side. We shall see that the inferior limb of the anterior Y is not directed straight downwards, but slightly to the nasal side.

By injecting a concentrated solution of salt either into the anterior chamber or vitreous, we will cause a whitish haze of the lens, which will first occupy the corresponding cortical portions, which afterwards will become more or less clear, while the cloudiness becomes more central. This artificial cataract, like the traumatic cataract, causes the design of the sutures to appear more or less.

In the eyes of chicken, left *in situ* for several hours, we will see on the posterior surface of the cornea numerous folds of the membrane of Descemet, which we will examine by trans-illumination and direct light. In these we will study double reflexes, sometimes very bright, joining one another in places.

The shape and distribution of the pigmented cells of the iris may be studied in a wall-eyed pig.

The delicate investigation of the endothelium of the cornea may be learned on the globe of a domestic animal, pig or ox. We will focus the microscope on the zone of specular reflection of the posterior surface of the cornea, in which we will see appear the carpet of hexagonal cells of the endothelium. With sufficient magnification (oc. 4, obj. *a* 3), and if the eye is fresh, we will see a dark nucleus in the middle of each cell.

CHAPTER III

PHENOMENA OF REFLECTION OF LIGHT BY THE OCULAR MEDIA

In ophthalmoscopy the light reflexes at the surfaces of the different transparent media of the eye play quite an inopportune part. To understand ophthalmoscopy is to understand how to avoid reflexes, and the aim of the modern ophthalmoscope is to solve the problem and not cause any luminous reflex at the surface of the cornea or lens.

In ocular microscopy it will be our endeavour sometimes to avoid the reflexes, sometimes to use them rationally.

A study of the phenomena of reflection of light by the transparent media of the eye is necessary to understand the following chapters.

The ocular media comprise several *zones of discontinuity*, taking on the form, more or less, of a spherical cap. We know that physicists give the name "zones of discontinuity" to optical surfaces where the index of refraction suddenly changes. A luminous beam striking such a zone provokes certain optical phenomena, of which we will only study those of reflection, leaving on one side refraction, polarisation, diffraction and fluorescence. One part of the rays is reflected according to the laws of *regular reflection*, the reflected rays being contained in the same plane as the incident, and their respective angles being equal. As to the direction of the refracted rays, this is given by the formula of Snell-Descartes :—

$$\frac{\sin \alpha}{\sin \beta} = n.$$

The proportion of light reflected varies with the surfaces and depends chiefly—

(*a*) On the difference of indices of refraction of the media considered ;

(*b*) On the degree of polish of the reflecting surface ;

(*c*) On the size of the angle of incidence.

For the same surface we only take into consideration the size of the angle of incidence.

Light reflected regularly produces an *image* of the luminous source at the point of convergence of the rays, if it be a real image, or of the prolongation of the rays, if it be a virtual image.

An eye placed in the direction of the regularly reflected rays receives the *specular reflection* of the surface, its *reflex*. The colour of the reflex depends principally on the colour of the light used. In sunlight, all specular reflection is white.

Now, one part of the incident light is reflected in a *diffuse, irregular* fashion. This phenomenon is noticed on the surface of all bodies, and renders them visible to us.

In the transparent media of the eye we meet, then, at each zone of discontinuity, a diffuse reflection, rendering the surface visible, a regular reflection forming an image of the luminous source, an image which we perceive if we are in the path of the reflected rays, and which is more or less mingled with the *zone of specular reflection*—that is to say, the portion of the reflecting surface where reflection takes place. We shall see also virtual images by accommodating for them, although we are unable to project them on a screen.

These principles of optics are necessary to understand the phenomena of light which the slit-lamp produces in the ocular media. By means of this source of light, and with the microscope, it will be possible to distinguish quite easily the zone of specular reflection from the image. The discrimination of these two things is due to Vogt, who has shown the great clinical importance of the zones of specular reflection.

Modern authors, working with the slit-lamp, have not at first understood the importance of these zones, but have, on the other hand, tried to avoid these reflexes. In his work on ocular microscopy, although it is so full of detail, Koeppe has said nothing original on this point. Gallemaerts and Kleefeld (*Ann. d'oc.*, 1920), do not mention zones of specular reflection.

Nevertheless, Stähli recommends, so as to see certain details of the cornea, examination " in the reflex " with a loupe, with a luminous source of great brilliance. A long time ago Tscherning made an important remark on the anterior image of the lens : " After having found the image, one should concentrate the light on to the eye ; by this means one enlarges the image, which goes on to fill the entire pupil. If the light is bright, the pupil often appears white, as if the eye were the subject of a ripe cataract, and one can, by examining with a loupe, also observe anatomical details which one is unable to find by any other means. I recommend this examination to clinicians, a description of which I have not found elsewhere " (*Optique physiologique*, 1898, p. 41).

It is to be noted that what Tscherning calls image is nothing else than the zone of specular reflection.

REFLECTION OF LIGHT AT THE SURFACE OF THE CORNEA

The surface of the cornea offers the best conditions for regular reflection. Its degree of polish is high in the normal state.

The difference between the indices of refraction air : cornea is pronounced (1 : 1·377).

The cornea being illuminated by the luminous beam of the slit-lamp focussed upon its anterior surface, we see, for all angles of incidence, a clear rectangle figured on the cornea, due to *diffuse* reflection. This *anterior band* of the cornea varies little in luminosity, whatever may be the angle of incidence, or that of observation. It is visible from all points.

It is not the same with the reflex due to regular reflection. To see this the observer must place himself in the direction of the reflected rays. At this moment the angle of observation (formed by the axis of the microscope and the normal to the surface of the cornea) will be equal to the angle of incidence. *By focussing the microscope on the cornea at this spot we obtain the zone of specular reflection.* This does not completely fill the anterior band, but only a part, chiefly of importance in the horizontal meridian of the cornea or its immediate neighbour-

hood. *The smoother the cornea the more limited is the zone, but the less pronounced it is.* The image itself will be found situated at another spot. If the rays are parallel it will occupy the catoptric focus of the corneal surface, about 4 mm. deep. Knowing the convergence positive or negative (divergence) of the incident rays, we easily determine the exact position of the image in each case. Whatever be the incidence of the luminous rays, we only perceive the image with the microscope if we see the zone of specular reflection. These rays being parallel, we only see the image sharply figured if we focus more deeply : the eye of the observer, the zone of specular reflection and the image of the luminous source are all in the same straight line.

We can study these conditions in the enucleated eye of the pig, for instance, quite well, the source of light being formed by an electric light placed behind us. To maintain the polish of the cornea, we must take care to moisten the globe continually.

If we examine with the binocular microscope and slit-lamp either the zone of specular reflection or the image, and if we close the eyes alternately, we notice that they present a maximum intensity in one of the eyepieces. As a matter of fact, the reflected beam is too narrow to strike the two objectives equally.

In reality, in microscopy on the living, we never have the beam formed of parallel rays. If the lamp is arranged according to the original method, the luminous filament is found at the anterior principal focus of the condenser, itself composed of two plano-convex lenses, which projects the image of the filament into the slit, which thus serves as the secondary source of light. The illuminating lens collects the rays and projects a convergent luminous beam about 8 cm. in length (if the lens has a focal length of 7 cm.). We may distinguish a *pre-focal* portion, composed of convergent rays, and a *post-focal* portion, formed of divergent rays. A real image of the filament, which may be received on an appropriate screen and photographed, is formed at the principal focus of the lens, and this, as a matter of fact, may be considered as the source of light.

There are three cases to be considered, depending upon whether the anterior surface of the cornea is situated, in the

examination, at the focus of the beam itself, in the post-focal portion (divergent rays) or in the pre-focal (convergent rays).

(*a*) The surface of the cornea is found at the focus itself of the beam. The luminous band has reached its maximum brightness, marked off as a regular rectangle, the width of which depends upon that of the slit. The filament is found figured on the cornea, and acts as a luminous source. The catoptric image of this luminous source will be found situated at the same spot. *This is the only case where there is a coincidence between the zone of specular reflection and the catoptric image of the source of illumination.*

We may also consider the spot where the catoptric image of the *diaphragm of the illuminating lens* is formed. This lens is situated in front of the mirror formed by the anterior surface of the cornea, and its image will be found between the summit of the cornea and its catoptric focus.

We can verify these deductions on the living cornea, or, in case of need, on that of the enucleated globe. We bring the focal part of the luminous beam exactly to a focus on the anterior surface, and place the microscope in the axis of the rays reflected regularly. We note that the zone of specular reflection, which only occupies a portion of the anterior band of the cornea, coincides with the image. The maximum sharpness of focus of the zone of specular reflection, which we recognise by small irregularities of surface, coincides exactly with that of the image. Now let us advance the microscope. The details of the filament disappear, and at a given moment the reflection takes on the regular form of the diaphragm of the illuminating lens. We are now focussed on the catoptric image of the diaphragm, situated very near to the principal focus, and therefore deeper.

(*b*) The surface of the cornea is situated in the post-focal part of the beam. The rays are here divergent. The *dioptric* image of the filament acts as a luminous source, the catoptric image of which will be situated between the summit of the cornea and the catoptric focus.

It will be the same for the image of the diaphragm. As this

is further removed from the cornea than the luminous source (dioptric image of the filament) the catoptric image of the diaphragm will be situated nearer to the catoptric focus of the cornea—that is to say, it will be deeper (*cf.* Fig. 11).

The experimental verification of the above explanation is easy. Let us project on to the cornea the divergent part of the beam, and focus the microscope on to the zone of specular reflection, which naturally appears on the surface of the cornea. At this spot we see no image. To find the image of the filament

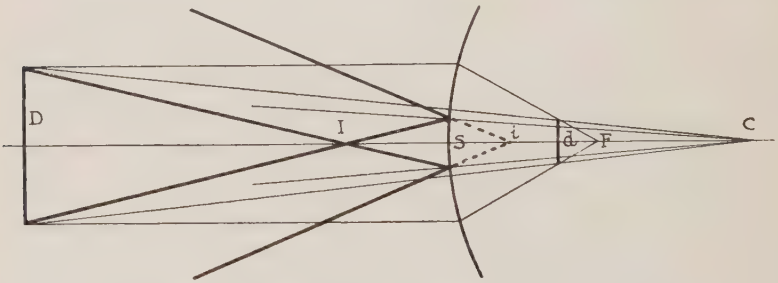

Fig. 11.—Diagram representing the examination of the cornea in the post-focal part of the luminous beam. Formation of the catoptric images of the diaphragm of the lens and of the filament, by the convex mirror of the corneal surface. D. Diaphragm. *d.* Its image. I. Dioptric image of the filament. *i.* Its catoptric image. S. Summit of the mirror. F. Its principal focus. C. Its centre of curvature. The lamp is arranged here according to the original method (formation of the image of the filament in the middle of the slit). The plane of the diagram corresponds to a vertical plane.

we shall have to advance the microscope. It is necessary to focus on to a plane still deeper to see the rectangular image of the diaphragm of the illuminating lens appear.

(*c*) The surface of the cornea is situated in the pre-focal portion, composed of convergent rays which strike the cornea before the dioptric image of the filament is formed. Depending upon the place where the prolongations of the rays intersect, several possibilities are to be considered.

1. The prolongations of the rays cross between the summit of the convex mirror of the cornea and its catoptric focus. The real catoptric image of the filament is placed, then, in front of the cornea.

2. The prolongations of the rays of the beam cross one another at the catoptric focus of the corneal surface. The catoptric image is projected to infinity.

3. The crossing of the prolonged rays occurs between the catoptric focus and the centre of curvature of the convex corneal mirror. The catoptric image, again virtual, is found behind the centre of curvature.

4. The rays, prolonged, cross at the centre of curvature itself. The image is at the same spot.

5. The intersection of the prolonged rays occurs behind the centre of curvature. There will then be a catoptric image between the centre of curvature and the focus.

As to the image of the diaphragm of the lens, it will be formed as under (*a*) and (*b*) between the catoptric focus of the convex mirror and its summit.

The experimental verification of these considerations is a little more delicate than those of (*a*) and (*b*). First of all, we focus the beam and the microscope on to the surface of the cornea. Carefully advancing the lens, we obtain convergent rays. To see the image of the filament, it will be necessary to withdraw the microscope. If the beam is brought sufficiently near to the cornea for the catoptric image of the filament to form behind the centre of curvature, we will notice that it is necessary to advance the microscope considerably, so as to see it sharply. It is a little ticklish to focus these images. As to the image of the lens, it is easily found between the focus and summit of the cornea.

The conditions are more complicated if the lamp is arranged according to the new method of projection of the rays (Vogt). In this method the filament is moved towards the condenser until the moment at which it is projected upon the illuminating lens, and no longer on to the slit, which here only plays the part of a diaphragm (*vide* p. 8, and Fig. 1). This arrangement considerably increases the homogeneity of the beam in its focal portion, the most important, and favours a sharp marking of its boundaries. The beam contains in reality two images, that of the filament and that of the slit, which do not coincide,

since the two objects are not at the same point. The image of the filament is found in the diaphragm of the illuminating lens and that of the slit in the focal part of the beam. So that, in the new method of projection, where we had previously the image of the filament, we have a homogeneous rectangular area, and where we found the image of the diaphragm we have now the image of the filament limited rectangularly by the diaphragm. In itself, the focussing of the images has only a theoretical interest.

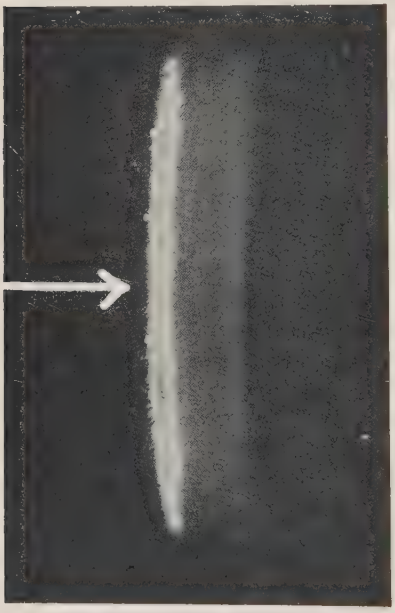

FIG. 12. -Photograph of the cornea, taken with the microscope (obj. *a* 2, oc. 2). Diffuse reflection of light coming from the left. Microscope and beam are focussed on the anterior band. The posterior band is less sharp because it is not in focus. It is always less luminous than the anterior.

We do not, naturally, see in the images any details of the tissues. It is quite different with the zones of specular reflection, which allow extremely minute inequalities of surface to be detected.

At the surface of the cornea we see in the zone of specular reflection corpuscular elements, mucus and *débris* of cells, conveyed by the tears, which form a very thin layer, giving rise to phenomena of interference. Pathological changes considerably modify the zone (œdema, etc.), giving to it a shagreened or speckled appearance and increasing the irregular reflection at the expense of the regular. In glaucoma, for example, the zone is badly delimited, and in its interior *epithelial bedewing* shows itself under the form of a multitude of small protuberances. After blinking, these protuberances suffer a momentary eclipse. After the instillation of an oily

drop, fine droplets of grease may still be found after several hours.

Fig. 12 represents the more or less diffuse reflection on the cornea and in its interior. The light comes from the left. We distinguish on the left the anterior band of the cornea. To the right the corneal stroma provokes but a feeble reflection, the same as the posterior surface. The beam and microscope are focussed on the anterior band, in which we see some white spots, which are inequalities of surface produced by dessication of the cornea. Whatever may be the angle of incidence of the luminous rays, the anterior band is always more luminous than the posterior. The surface of the cornea is, of all the reflecting surfaces of the eye, that at which reflection is most pronounced.

The band, the image and the zone of specular reflection are, then, three things which we must not confuse.

The band is due to diffuse reflection.

Also, it is seen from all sides, and its brightness does not vary appreciably ; but it is more or less luminous, according to the nature of the tissues.

The band has a rectangular form, more or less curved. Its height depends upon that of the beam and also—

(*a*) On the method of projection. In the method of Vogt, the band is twice as high as in that of Gullstrand ;

(*b*) On the illuminating lens. The greater its focal length, the higher the band.

It is, on the other hand, independent of the dimensions of the diaphragm of the illuminating lens.

The width of the bands depends solely on that of the slit.

The images are produced by the regular reflection of light.

A surface reflects much more light when it is smooth and when the difference between the indices of refraction of the two media is great. The amount of light reflected is also dependent upon the angle of incidence of the rays. The smaller this angle, the less the light reflected. In ocular microscopy, this factor has not a great importance, since one works, usually, with an angle of about 40°.

The zones of specular reflection are rendered visible by light reflected irregularly.

The more a surface is regular and smooth, the more is the reflection intense and the image sharp (a silvered mirror, for instance), and the more difficult is it to find a zone of specular

FIG. 13.—Photograph of the catoptric image of the luminous slit produced by the surface of the cornea. The lamp is arranged so that the image of the filament is formed on the illuminating lens (usual method). The image of the slit, very luminous and homogeneous, is situated in front of the cornea.

FIG. 14.—Photograph of the zone of specular reflection of the cornea. The lamp is arranged in the usual method. The beam not being exactly focussed on the cornea, the zone of specular reflection is not sharply delimited. The microscope, however, is exactly focussed on to the artificial cornea, on which may be seen dust and irregularities of surface.

reflection. An ideally smooth surface has no zone of specular reflection.

Let us take a reflecting surface of given convexity. It will form, if it is struck by a parallel beam of rays, an image of the source at the catoptric focus. If the microscope is focussed on this surface, we shall not see sharply a catoptric image, because it is not at this level. Let us grant that the said sur-

face presents a certain number of small irregular eminences and also minute depressions. These secondary irregularities produce, in their turn secondary, catoptric images, the collection of which constitutes the zone of specular reflection which our microscope will perceive, the radius of curvature of these secondary inequalities being so small, and the images, therefore, being very near to the primary surface.

FIG. 15.—Catoptric image of the illuminating lens reflected by the cornea. The lamp being arranged in the usual method, the figure of the filament is seen. This image is situated behind the cornea.

FIG. 16.—Photograph of the zone of specular reflection of the cornea. Usual method of projection of the luminous rays. The beam and microscope are focussed on the cornea.

We illustrate the considerations we have explained above by some photographic evidence. For many reasons, it is not possible to obtain good photographs in the living. We have used an artificial cornea, opaque and very smooth, which allows us to consider only the reflection at the surface. The cornea has been illuminated by the beam of a slit-lamp, and we have used the microscope to take the photographs. The time of exposure has been the same for all the pictures.

Let us suppose that the beam falls on the cornea with such a convergence that the prolongations of the rays cut one another between the summit and posterior focus.

Advance the microscope towards the cornea. First we find Fig. 13, which is nothing else than the catoptric image of the luminous slit, the image produced by the convex mirror of the cornea and which we find in front of it. The image of the slit is very luminous and absolutely homogeneous.

Continue to advance the apparatus until it is focussed on the cornea itself. Immediately we see Fig. 14, which is the zone of specular reflection of the cornea. It is more or less stippled, and shows black dots produced by dust.

Keep advancing the microscope. Soon we shall stumble upon Fig. 15, which is the image of the illuminating lens, limited rectangularly by its diaphragm. We shall recognise the figure of the filament. In reality, in projecting the rays according to the method of Vogt, we form the image of the filament exactly on the lens. As it is situated in front of the cornea, its image is placed between the summit of the cornea and its catoptric focus. It may be remarked in passing that it is always this image which the patient sees when he looks towards the lamp.

Finally, we are able to focus the beam exactly on the surface of the cornea. We shall then obtain Fig. 16. In this, the image of the slit is formed exactly on the cornea. Its catoptric image is at the same spot. The zone of specular reflection has its best definition here. It is this focussing that we employ with the microscope when we examine the zone of specular reflection. Nevertheless, when we examine a reflecting surface other than the surface of the cornea, we also meet, whether we wish it or not, Figs. 13, 14, 15, and it is for this reason that their recognition has not merely a theoretical interest.

REFLECTION OF LIGHT IN THE INTERIOR OF THE CORNEA

The beam of the lamp cuts in the cornea a parallelepiped, the anterior surface of which is the anterior band, and the posterior

surface the posterior band. By reducing the slit as much as possible we obtain almost an *optical section*.

In the normal condition the cornea produces in its interior a more or less diffuse reflection, which, without being very much accentuated, is, nevertheless, easily appreciated. It is far from being homogeneous, but one does not, however, see any regular design which would correspond to lamellæ or lymphatic spaces (systems of Bowman or Recklinghausen). The epithelium itself is normally homogeneous. The membrane of Bowman is invisible. It becomes perceptible when it forms folds around a foreign body or a cicatrix.

Koeppe distinguishes in the interior of the cornea a system of lymphatic canals, a system of lamellæ, which in inflammatory conditions stand out markedly. But it seems that this discrimination belongs rather to a theoretical assumption than to objective verification. It is the same with the "arachnoid corpuscles."

We often see, in the enucleated eyes of the pig, a very fine striation formed of streaks, alternately dark and light, almost straight. We also distinguish a second striation, more or less at right angles to the former. The streaks are not parallel to the surface of the cornea, but slightly oblique. This phenomenon is possibly caused by a *post-mortem* imbibition. The striation recalls the lamellar separation so frequent in senile cataract (Vogt).

We may point out that the cornea may present the phenomena of *total reflection* when the incident rays strike the cornea with a sufficient incidence. If we illuminate the limbus on the temporal side with a wide angle of incidence, we see appear on the limbus, on the nasal side, a bright crescent; at the same time the angle of the anterior chamber and the neighbouring parts of the iris become illuminated. This illumination is produced by luminous rays which have penetrated the cornea, are reflected alternately by the posterior and anterior surfaces, and then reach the opposite limbus.

Other explanations have been given of these phenomena, which seem to us erroneous.

REFLECTION OF LIGHT BY THE POSTERIOR SURFACE OF THE CORNEA

Reflection is less pronounced at the posterior surface of the cornea than at the anterior. The difference of the indices air : cornea is much greater than that of the indices cornea : aqueous humour (1 : 1·377 and 1·377 : 1·3365). Besides, a part of the light reflected by the posterior surface is absorbed by the cornea, or reflected inwards by the anterior surface. Theoretically there should be an opportunity to view the reflection at three places : at the surface of Descemet's membrane, at the anterior surface of the endothelium, and at its posterior surface. It is not possible to determine exactly what portion is reflected at each of these surfaces. The membrane of Descemet is not visible in the normal state. We do not know its index of refraction.

The light reflected, be it regularly or irregularly, has a more or less yellowish tint. This coloration is due, in part at least, to the fact that the cornea chiefly absorbs rays of short wavelength. This absorption occurs twice, because the rays have to traverse the cornea to reach its posterior surface, and, to reach the observer, they have to traverse the cornea a second time after reflection by the posterior surface.

If the beam be projected on to a coloured glass, the anterior band is always more or less whitish, whatever be the colour of the glass, while the posterior is obviously coloured.

For regular reflection at the posterior surface, the laws set forth above for the anterior surface are equally applicable. But we must bear in mind that the light has been refracted and rendered more convergent by the cornea, and that the principal foci and centres of curvature of the anterior and posterior surfaces do not coincide. Practically, these differences may be neglected.

Catoptric images formed by the posterior surface of the cornea are less luminous and less sharp than those of the anterior surface. One circumstance contributes also to

render them less visible. They are always situated very near to the anterior images, the luminosity of which is such that it hinders considerably the perception of the posterior images.

The posterior zone of specular reflection has a great clinical importance. It is in it that we see the endothelium, composed of hexagonal cells. In the peripheral portions of the cornea we notice dark gaps caused by interruptions of the zone of specular reflection, where the endothelial layer is more or less bulged backwards.

According to Vogt, these formations are identical with the *verrucosities* of Hassal-Henle. It is certain that the older the subject, the more numerous they are.

From the pathological point of view, the posterior zone of specular reflection plays an important *rôle*. The first alterations in irido-cyclitis show themselves at its level : microscopic precipitates, endothelial bedewing, etc. The researches of Vogt, and of Schnyder, have shown that the endothelium is an extremely sensitive index. Different forms of keratitis, apparently superficial (epithelial dystrophy of Fuchs, various types of œdema, etc.), are accompanied by changes in the endothelium, of which as yet little is known.

QUANTITY OF LIGHT REFLECTED REGULARLY

Hartinger has calculated theoretically, by the aid of constants furnished by Gullstrand, the quantities of light reflected regularly by the cornea and lens. For these calculations he assumes that the incident rays strike the cornea almost perpendicularly at a point very near to the optic axis, and publishes the following figures :—

Quantity of light reflected by the surface of the cornea	25	per 1,000
Quantity of light reflected by the posterior surface	0·22	,,
Quantity of light reflected by the surface of the lens	0·34	,,

Proceeding also from the theoretical point of view, Raeder (*Arch. f. O.*, vol. cx., p. 80, 1922) obtained slightly different figures :—

Quantity of light reflected by the cornea .	25 per 1,000
Quantity of light reflected by the posterior surface	0.24 ,,
Quantity of light reflected by the anterior surface of the lens	0·36 ,,
Quantity of light reflected by the posterior surface of the lens	0·36 ,,

We see, then, that the anterior reflex is almost a hundred times more luminous than that of the posterior surface. In reality, in the microscope, an amount of light very much greater is reflected, because the angle of incidence of the luminous rays is, on an average, 40° (measured with the normal to the cornea).

We understand, also, the difficulty which an examination of the posterior surface and its endothelium presents, these objects being much less luminous than the reflex from the anterior surface, and at the same time the impossibility of obtaining good photographs of the endothelium.

REFLECTION OF LIGHT BY THE STRUCTURELESS MEMBRANES

The reflection of light at the surfaces of the structureless membranes (Bowman, Descemet, lens capsule) causes peculiar appearances, which it will be much more convenient to study when we meet them singly in pathological conditions or traumatic changes.

We observe more or less linear reflexes when these membranes are folded. These reflexes have constant properties that have been explained by Vogt.

(*a*) They appear almost always joined in pairs.

(*b*) They are always more or less parallel, two by two.

(*c*) They converge and often fuse at their extremities.

(*d*) They may be made to move in a characteristic fashion by altering the angle of incidence of the light or the angle of observation.

We can study these reflexes on a surface composed of parallel cylindrical mirrors alternately convex and concave.

Let E be the angle of incidence of the light, B the angle that the direction of regard of the observer makes with the normal to a plane tangential to the summits of the mirrors. We can show that, if the radius of curvature of the mirrors be altered, E and B remaining constant, the movement of the reflexes from the line of junction of the mirrors is proportional to the radius of curvature. Expressed differently, the movement of the reflexes from the summits of the mirror is a function of $\frac{E + B}{2}$. For all values of $\frac{E + B}{2}$, the reflexes appear in pairs, except in the special case, when $\frac{E + B}{2} = 0$.

On the other hand, complete parallel cylinders only give simple reflexes due to their convexity.

We can observe these reflexes on the folds of the cornea of the cadaver, the peritoneum of the frog, etc. In general, the more elastic a membrane, the less tendency it shows to become folded, so that it must be admitted that the membrane of Descemet lacks elasticity, since it folds so easily.

Clinically, with the aid of the slit-lamp, folds may be found in Descemet's membrane after the operation for cataract, in interstitial keratitis, etc. Bowman's membrane is seldom folded. These reflexes may be confused—

(*a*) With opacities along the nerves of the cornea, but these show a dichotomous ramification ;

(*b*) With tears of Descemet's membrane in hydrophthalmos, but these are broader, always occupy the same position, and do not have double reflexes ;

(*c*) With vascular remains, which are easily recognised by transillumination.

REFLECTION OF LIGHT BY THE LENS

In the lens we have chiefly two very smooth surfaces of discontinuity, producing images by the regular reflection of light : the anterior and posterior lens capsule. For a long time oculists recognised the presence of the lens by that of the Purkinjé-Sanson figures. The diminution in size of the illuminating surface and the increase in its brightness have enabled more precise observations to be made by Helmholtz, Tscherning, etc., but it is the slit-lamp alone which has caused the enormous advancement in our knowledge.

Purkinjé described, in 1823, four images. The first is erect, very bright, and produced by the anterior surface of the cornea. The second erect, much less bright, is due to the reflection at the posterior surface of the cornea. The third, less bright than the first, is also erect, and owes its origin to the anterior surface of the lens. Finally, the fourth, inverted, arises from the posterior surface of the lens. The first three images are displaced in the same direction as the source of light, the fourth in the opposite direction. Blix and Tscherning rediscovered and studied in detail the second image. Only the first image is purely catroptic, but one may, with Tscherning, consider that each image is produced by the reflection on a single *apparent* surface. This surface allows us to calculate the position of its image.

Demicheri (*Annales d'Oculistique*, vol. 113, p. 93, 1895) was the first to describe accessory images on the surface of the nucleus of the lens. Under the name *false lenticonus*, he collected different cases, having in common hypermetropia of the peripheral parts combined with myopia of the axial parts. Aided by Tscherning, he observed the images of the anterior and posterior surfaces of the nucleus. " The catoptric images of the nucleus are diffuse. If it is true, then, that there is a separation or appreciable difference of index between the nucleus and the cortical layers, it is also true that this separation does not take place suddenly. There is, up to a certain point, a transition in the index." Depending on the fact that the

difference in refringence between the periphery and the nucleus sets in fairly suddenly—in several weeks sometimes—and that the cortex shows senile changes much more pronounced than the nucleus, Demicheri thinks that it is not the nucleus which increases but the cortex which diminishes its index.

Guttmann, reporting a case of "double refringence" later on, blames the nucleus alone, the index of which increases owing to loss of water. Similarly, von Szily, basing his views on the fact that peripheral hypermetropia is pretty rare and is not constant, as Demicheri says, thinks that the changes in refringence occur in the nucleus alone. Halben also thinks that we must admit that the nuclear refringence increases on account of loss of water. Later, von Hess drew attention to the possible changes in the curvature of the nucleus, which would naturally modify the refringence of the lens. As we shall see later, in the case of "false lenticonus," we must blame chiefly the changes in structure and refringence which take place in the nucleus.

Investigation of the images of Purkinjé is practised in veterinary medicine. Schmidt, so as to verify an observation of Hermann (1897), who saw in a horse more than three images, undertook a series of observations, which justified him in affirming the presence of a second erect image in the lens, and, less frequently, a second inverted image, in horses still young (seven years and more). This author admits that the visibility of these new images increases with age and that they are particularly pronounced when the cortex already shows slight changes. He has also noticed the presence of concentric circles in the lens, when it was examined in oblique diffuse light. Bayer,[1] who quotes these observations, does not care to express an opinion on the nature and origin of the supplementary images.

We owe to von Hess new observations on the reflection of light in the lens. He used a Czapski microscope, furnished with a small incandescent lamp. He proved that the anterior image of the lens is not only due to the capsule, but also to the

[1] Bayer, J.: *Augenheilkunde*, 1914 ("Handbuch der tierärztlichen Chirurgie und Geburtshilfe").

subjacent layers. It is for this reason that it is a little stippled. He observed, in 1905, an important point, that " in perfectly normal lenses in people of twenty-five years and over (occasionally sooner), a second erect image appears almost regularly, the luminosity of which increases with age, so that towards fifty to seventy years, it may be, in absolutely clear lenses, as luminous as the anterior." [1]

He called this new image the *nuclear image*, in contradistinction to the *cortical image*. He discovered, also, in elderly people, a second inverted image, the *posterior nuclear image*. If we move the source of light, the displacement of the nuclear images is less than that of the cortical images. The former images are also less well delimited and less luminous than the second. In general, of the two nuclear images, the posterior appears later than the anterior.

The perfection of the apparatus and the use of the Gullstrand slit-lamp have enabled us to extend much further the study of the phenomena of reflection due to the lens. But the images have lost their importance, as now the reflecting surfaces have become directly visible.

REFLECTION OF LIGHT AT THE SURFACE OF THE LENS

If the surface of the lens be examined by oblique light, it will be observed that only a small portion of the light is reflected at this level. Generally, the greater the age of the subject, the more pronounced is the reflection. If the source of light is placed on the temporal side, for instance, the portions of the lens situated near to the iris on the same side are those that shine most brightly. Towards the centre of the pupil the reflex is lost insensibly.

" Very often the lens, with age," says Landolt, " takes on a certain *pearly appearance* which, with the increase of the reflex of the anterior surface, visible chiefly by oblique illumination, easily leads the young practitioner to diagnose the commencement of cataract, which an examination by transmitted light

[1] von Hess : *Pathologie und Therapie des Linsensystems*, p. 11 (" Handbuch der gesamten Augenheilkunde "), 1911.

negatives." [1] Now this pearly appearance may be also produced in part by the differentiation of the adult nucleus and its anterior relief, which we shall meet again later.

The luminous beam of the slit-lamp, focussed upon the surface of the lens, figures there a luminous rectangle visible from all sides, which is due to light reflected in an absolutely *diffuse* manner. If we happen to be in the plane of *regular* reflection of the light, we shall see a characteristic glittering shagreen. The zone of specular reflection only occupies a small part of the *anterior band*. It is found chiefly in the vicinity of the horizontal diameter of the pupil, the eye being supposed to look in front of it. There is found, naturally, as in the cornea, a catoptric image of the luminous source. This image, less sharp than the other, may be completely overlooked.

The peculiar appearance of the lens has been described by von Hess and by Vogt under the name of *shagreen* of the lens. It is due to an absolutely normal phenomenon which may also be found at the posterior pole of the lens and which will be described in detail later on. From the optical point of view, the light of the zone of specular reflection is composed of rays reflected in an *irregular* manner by the minute irregularities of the capsule, epithelium and superficial layer of lens fibres.

REFLECTION OF LIGHT IN THE INTERIOR OF THE LENS

At birth the lens of the infant is almost ideally transparent and there is hardly any diffuse reflection in the interior. Now the successive layers applied during the course of life are less transparent and present a slightly more diffuse reflection. Besides, as they are not identical from the optical point of view, there are formed areas of maximum reflection wherever the variation in index of refraction is sufficiently marked. In other words, in the luminous beam of the slit-lamp there will be a more or less luminous *band* at each of these zones of discontinuity. The more abrupt the variation of the index, the more luminous will be the band.

[1] Landolt: "L'influence de l'age sur la réfraction statique de l'œil," *Archives d'ophtalmologie*, 1918, p. 1.

Different layers of the lens also become visible at first sight, and there is no need to have recourse to the catoptric images.

Discovered by Gullstrand, minutely studied by Vogt and Meyer, the surfaces of discontinuity of the lens may be connected with the fœtal nucleus, with the adult nucleus, which contains the fœtal, with the capsule and the layers immediately subjacent. The following are the principal bands, passing from before backwards :—

1. Anterior band of the lens.
2. Anterior band of the adult nucleus.
3. Anterior band of the fœtal nucleus.
4. Posterior band of the fœtal nucleus.
5. Posterior band of the adult nucleus.
6. Posterior band of the lens.

Naturally all these bands will only be found in adult lenses. A certain amount of variability will, moreover, be noted, so that lenses of the same age will not be absolutely identical. On the other hand, the two eyes are, as a rule, exactly similar.

Between the anterior and posterior bands of the embryonic nucleus is seen a dark space, the *central interval*, which appears perfectly homogeneous. Sometimes also the bands, the anterior as frequently as the posterior, of the embryonic nucleus appear doubled, so that an external may be distinguished from an internal band. The embryonic bands, moreover, are the least sharp.

Several bands very near to one another may be present where, as a rule, we only see one. The rather schematic division given above has only for its object convenience of grouping.

In a general way, the bands are much more sharp when the beam is well focussed upon them. In this way there will only be one or two that are strictly in focus. But it is easy, by advancing or withdrawing the illuminating lens, to review them all.

The central interval may be seen on the *section* of the beam, that is to say, on the lateral surface of the pyramid which

forms the beam, more especially on the surface turned towards the observer. If then the lamp is situated to the left of the observer, its lateral surface will then be turned to his right. In the same way, a very diffuse opacity or the colours of a crystal will be able to be seen on the *optical section*.

We shall see later that we make use of certain anatomical criteria to identify exactly these diverse bands.

A *narrow beam* (*vide supra*, p. 14) makes the discrimination of these various surfaces of discontinuity much easier. The bands become narrower, sharper, and the intervals between them become greater on the section.

The surfaces of discontinuity in the interior of the lens are not so pronounced—the variation of the indices of refraction are not sufficiently abrupt for *zones of specular reflection* to arise. Only the surface of the adult nucleus is able to produce a feeble *zone*. But the light is reflected in a still more irregular fashion than at the surface of the lens.

REFLECTION OF LIGHT AT THE POSTERIOR SURFACE OF THE LENS

The posterior surface of the lens acts as a concave mirror, which reflects a portion of the light of the beam and forms a catoptric image of the luminous source. In the posterior band may be distinguished, more especially in the neighbourhood of the posterior pole, a zone of specular reflection which shows a shagreen similar to that of the anterior surface of the lens. On account of the greater curvature of the posterior surface the specular zone is at this point smaller than the anterior. As to the luminosity of the zone of specular reflection, it appears greater behind than in front.

PROJECTED SHADOWS

We may see appear, in the transparent media of the eye illuminated by the Gullstrand lamp, and in certain conditions, *projected shadows* limited by lines more or less parallel, depending upon the focussing of the luminous beam. These shadows may arise in two conditions :—

(*a*) When a less translucent object is situated in the luminous beam, *absorbing* more light than the neighbouring parts, or *diffusing* it more (a localised nebula, for instance).

(*b*) When there occurs an object having an index of refraction different from that of the surrounding part, especially if this object happens to be limited by smooth curved surfaces.

In the two cases, if the projected rays encounter a zone of discontinuity sufficiently pronounced, *they are projected there as on a screen* and will be seen to map out the shape of the object giving rise to the shadow. This happens particularly with the cornea, where alterations of the anterior surface are seen projected on to the posterior surface.

Fig. 17. — Photograph representing the shadows projected by an opaque object (above), and by a body reflecting the light (below) in the interior of the cornea. The light comes from the left and the objects are mapped on the posterior surface by the shadows. Above is a particle of mucus and below an air bubble situated on the cornea photographed under water. Note the two principal reflexes of the bubble.

We imagine that this phenomenon may lead into error an observer who has not been warned.

Fig. 17 shows two projected shadows. The first is produced by a particle of mucus (condition of *a*) ; the second by a vesicle (condition of *b*. In reality it happens to be an air bubble, but this makes no difference). We see the projected shadows standing out black in the more clear stroma of the cornea. The changes of the anterior band of the cornea are seen also mapped out in the posterior.

It is a little unexpected that bubbles or vacuoles, which are much more transparent than the surroundings, can throw a shadow on the deeper planes. That arises from the fact that their surfaces, both anterior and posterior, being smoother than the layer which contains them, cause a more powerful reflection of light than the surroundings, even if the index of

refraction of the bubble is almost the same as that of the surroundings. *This more powerful reflection shows itself by two reflexes that may be very bright*, and the projected shadows of these objects receive less light in consequence.

Vessels situated in the superficial layers of the cornea are sharply projected in this way on the posterior surface, in dark lines, which must not be confused with folds of Descemet's membrane. These phenomena may be seen at the periphery of a cornea with marginal degeneration (*vide* p. 78). Vesicles situated in the epithelium, well-marked infiltrations, etc., are similarly projected on the posterior surface in such a way that it is sometimes imagined a definite change exists at this point. But the projected shadows betray the superficial changes.

After the fortieth year we see fairly often, in the superficial layers of the lens, one or more rounded or oval vacuoles which give rise to a little reflex or possibly two, and throw a shadow on the deeper planes. In advanced cataract the vacuoles multiply to the point of producing a veritable sub-capsular carpet. Seen by transillumination, and depending upon the direction of the luminous rays, the vacuoles appear bordered by a dark line in the form of a ring or a crescent.

We may always see, if the bulla is sufficiently large and its contents homogeneous, that it acts as a lens concentrating luminous rays and that two tracks of shadow surround a more luminous cone (*cf.* Antonin Sacha). Now, so that a bulla situated *in* the cornea or lens may be able to act as a convergent element, it is necessary that its index of refraction be greater than that of the medium in which it is situated. In the opposite event it acts as a divergent element and throws a shadow surrounded by a more luminous zone.

In the same way, deposits of pigment, newly formed vessels creeping on the capsule, produce projected shadows.

CHAPTER IV

THE CONJUNCTIVA

SPECIAL TECHNIQUE

Examination of the bulbar conjunctiva offers no difficulty, this membrane being, like the cornea, easily accessible.

If one wishes to examine a large area at once it is advisable to mount the lamp according to the method of Gullstrand, so as to obtain a large uniform field, whether in the pre-focal or post-focal part of the beam. This method of mounting is also desirable when judging of the colour of a certain area of the conjunctiva. The method of the *astigmatic beam* of the author is, however, preferable (*vide* p. 13).

The part to be examined will be illuminated directly. As the conjunctiva is a transparent membrane resting on the background of the sclera, which is only slightly translucent, a great part of the light rays will be reflected and will render the conjunctiva visible by transmitted light. It is not possible here, as in the case of the cornea, for example, to distinguish different modes of illumination. *Red-free*[1] light has been recommended for the examination of conjunctival vessels. With this light they appear black on a bright green background. But the red-free filter absorbs so much light that its advantage is not apparent. It might be used, however, with an arc lamp.

THE NORMAL CONJUNCTIVA

The conjunctiva, being a transparent membrane, is recognised by its *vessels*. These form a freely anastomosing network which inflammatory conditions and the instillation of irritating collyria differentiate still more clearly. A very red superficial

[1] We call *red-free light* a light containing no red, but only rays of a wavelength of 410 to 560 millimicrons, which Vogt advocated for ophthalmoscopy, where it gives remarkable results (*cf.* Koby: "L'ophtalmoscopie de l'œil normal à la lumière privée de rayons rouges," *Revue générale d'ophtalmologie*, 1920, and "L'ophtalmoscopie de l'œil malade à la lumière anérythre," *ibidem*, 1920).

network may be distinguished from a deeper one which is slightly veiled, belonging to the episclera. Blinking, by causing the conjunctiva to become slightly folded, moves the superficial network, which, after gliding for a short distance over the deeper one, returns to its original place. The two systems of vessels are, moreover, connected.

It is not always easy to distinguish the veins from the arteries, the difference in colour being almost inappreciable and the direction of the blood flow not always discernible when the vessel is widely patent. It is especially in the cornea, in vessels which are narrowed or undergoing reabsorption, that it will be possible to examine the circulation, because it is not affected by blinking.

The rate of the blood flow in the conjunctival vessels, estimated by that of the visible corpuscles, has been measured by Zeller. The principle, already employed by Basler, is to introduce into the ocular a mesh whose speed can be regulated. Zeller noted, for arterioles of a diameter of 0·01 to 0·03 mm., an average rate of 1·6 to 3·5 mm. per second. The rate is generally less in old people than in young. There is no constant relation between the rate of flow and the diameter of the vessel.

The *current* becomes *granular* whenever there is a temporary or permanent narrowing of the lumen of a small vessel. Red globules are then seen to circulate as if driven by an invisible force. Sometimes they pass one by one as on a chaplet, sometimes they are in groups.

The granular current is not, then, of pathological significance. It is particularly well studied after instillation of adrenalin. The following observation may be easily made : a vessel which, in the normal state, shows a granular current, may very well, under the influence of mechanical irritation, dilate so much that the red cells, adhering to one another, become invisible once more.

The *nerves* of the conjunctiva become visible, according to Knüsel, when, with the eye looking downwards, slight pressure is exerted on the upper lid. Brilliant white filaments, which branch dichotomously, then appear.

According to the same author, it is sometimes possible, especially in old people and high myopes, to see the expansion of the tendinous fibres of the rectus externus and sometimes, also, of the internus in the form of anastomosing parallel striæ, of brilliant appearance, which must not be mistaken for a cicatrix.

As for the *tissue* of the conjunctiva itself, it sometimes shows a fine parallel striation. This first system of striæ is cut by a second at a variable angle. In young people, fine radial fibres are sometimes seen, cut at right angles by circular fibres. In old people the conjunctiva seems to lose its transparency and its polish.

Repeated instillation of different dyes, methylene blue, neutral red, etc., has afforded Knüsel and Vonwiller, Gallemaerts, etc., interesting results, especially from the anatomical point of view. Methylene blue stains the superficial flattened cells with large nuclei. The epithelial nerve endings, which also stain with methylene blue (as do the vessels themselves sometimes), are more difficult to see. When the vessels are moderately stained, little blue stars, which Knüsel identifies with the cells of Rouget, contractile elements, are seen on the capillaries.

By putting into the conjunctival sac a drop of a 1 per cent. solution of Bengal red, Marx brought into relief a fine red rim at the edge of the lids and the two puncta lachrymalia.

Koeppe has described, with a wealth of detail, a *conjunctival lymphatic system*, which is composed of two elements : *perivascular* lymphatic vessels, each vein and each artery being surrounded by a lymph space, and *independent* lymphatics, all anastomosing freely. Other authors have confined themselves to reproducing faithfully Koeppe's description and diagram. In order to see these vessels, we are advised to use a magnification of 103 diameters, which, as we have said above, is not practicable on the living eye.

Vogt calls such a lymphatic system hypothetical. Knüsel has seen lymphatic spaces near the limbus in individuals in whom the " palisades " are clear. When a little methylene blue is

injected under the conjunctiva, more or less numerous tracks are seen starting from the vesicle formed. Ada Stübel, studying the conjunctiva *in vitro* by the method of Magnus, based on the decomposition of hydrogen peroxide by lymph, has noted the presence of irregular canals which do not form a well-defined network.

Ascher describes a superficial circumcorneal network, round which are disposed, especially in dark races, tracks of pigment, which make it particularly visible.

SENILE MODIFICATIONS

In old people, the conjunctival tissue seems less transparent and less uniform than in children. Whitish, fibrous bands, irregular in form, stand out from the rest. The surface of the conjunctiva (zone of specular reflection) also seems more irregular.

Modifications in the form of the vessels, possibly congenital deformities, are common : sacculated and fusiform dilatations, actual varices. These malformations are naturally exaggerated by stasis and by inflammatory processes.

Amongst **pigmentary changes,** the frequent pigmentation of the limbus must be mentioned. The yellow-brown pigment lies in a thin subconjunctival layer and is separated from the vessels by a clear space. There are also clear bands of uniform calibre throughout which are free from pigment. Vogt attributes a hæmatogenous origin to this pigment.

The **pinguecula** appears under the microscope as a small gelatinous mass, more often irregularly embossed. Sometimes the surface shows deposits, which are probably of a calcareous nature.

The researches of Hinnen show that the pinguecula is essentially a senile change. In fifty-seven children of six to ten years there was no sign of it. In 190 individuals of eleven to twenty years it was still absent in 93 per cent. of the cases. From fifty-one to sixty years its presence is observed in 97 per cent. of the cases, and it may be regarded as constant after

eighty years. Speaking generally, nasal pinguecula appears earlier than temporal.

Occasionally in old people, more or less transparent **cysts** are seen, rather resembling phlyctens, and situated in the region of the palpebral fissure. Sometimes they show calcification. The region surrounding these vesicles is usually vascularised.

TRAUMATIC LESIONS

Scars of the conjunctiva are recognised by their ivory-like appearance, the tissue being denser and less vascularised than that surrounding it. Often radial folds of the neighbouring conjunctiva give more or less linear reflexes.

Perforation of the globe is to be feared when a conjunctival wound is accompanied by a deep ecchymosis.

Scars of Elliot's trephine operations present a curious appearance. Generally one sees several transparent cysts attached. On examining these cysts by indirect illumination, a great number of fine pigment granules of uveal and retinal origin are found. On instilling a drop of fluorescin it may be noticed that the colour disappears much more rapidly round a filtering scar than on the rest of the globe (Seidel). This fact is, of course, evidence of a continual filtration.

PATHOLOGICAL CHANGES

Artificial pigmentations of the conjunctiva, of which the commonest type is **argyrosis,** are easily seen under the microscope. The conjunctival epithelium itself is found to be devoid of pigment. In the form of minute granules, it follows the course of the vessels and lies at the same depth. These observations corroborate those of Gabrielidès on the cadaver. The pigmentation extends over the whole conjunctiva, bulbar as well as palpebral.

This exogenous pigmentation must not be confused with the normal pigmentation appearing at the limbus in many dark-complexioned people.

Koeppe describes, in argyrosis, tiny epithelial vacuoles which,

on rupturing, give the lower fornix an appearance of shagreen. He attributes these changes to œdema of the epithelium.

In **siderosis** the pigment is of a rusty, autumn-leaf tint, but has the same distribution as in argyrosis.

Various stainings, usually diffuse, may be seen in persons working with **aniline dyes.**

In **Addison's disease** the conjunctiva may also be pigmented. In a patient, thirty-one years old, Meesmann has observed patches, not very clearly demarcated, in the interpalpebral space. In the largest, a system of lymphatic vessels was seen. The pigment granules were situated only in the conjunctiva and not in the episclera. At the limbus there was an almost black circle encroaching on the cornea and showing radial striation due to lymphatic vessels. These phenomena became less pronounced later. The same author has observed a similar pigmentation in a patient of seventy-three years.

We may notice, in passing, the truly *orange yellow* tint, which is due, according to von Szily, to a **fatty degeneration,** and which appears to be very rare. This author has examined two such cases histologically.

Several kinds of **vascular change,** said to be påthognomonic of syphilis, diabetes, etc., have been described. Without denying the importance of these changes, we may say that they are not sufficient in themselves to establish a diagnosis, and that they may very well be absent altogether. They have been noted, moreover, for the most part, before the invention of the slit-lamp (Coccius, Donders, Bajardi, Augstein, Streiff, etc.).

Zeller notices in **arterio-sclerosis** increased tortuosity of the vessels and frequent varices. The capillaries of the limbus encroach further upon the cornea.

In **syphilis,** fusiform or sacculated telangiectases of the venules and capillaries may be seen ; in **diabetes** a considerable enlargement of the venous branch of the capillaries. In one case Zeller has seen numerous spiral-shaped dilatations and miliary aneurisms, as well as a number of vascular glomeruli.

In a case of *arterial hypertension* (T = 200 mm.) Vogt has

observed the total obliteration of the capillary network at the limbus, from which he infers that general hypertension may very well be caused by obliteration of capillaries in general.

Small *hæmorrhages* in the course of even a simple conjunctivitis are not uncommon and disappear quickly.

Amongst vascular changes must be mentioned **angiomata,** composed of convoluted vessels resembling glomeruli, which are fairly common at the limbus. With the naked eye, one takes them for small hæmorrhages. They are met with in *arterio-sclerotic* subjects and seem to change only very slowly. One of Vogt's patients was suffering from hæmorrhagic retinitis in both eyes.

Two kinds of lesions are observed in **scrofula,** the well-known typical phlycten, in which the microscope discovers nothing new, and the much smaller and more numerous whitish vesicles. These last are of the size of a millet seed, and have a gelatinous appearance. They are situated especially in the region of the palpebral fissure and are usually very numerous, twenty to thirty in each eye. The globe is injected, even if the cornea is not involved, which is rather exceptional. After some days they become umbilicated and seem to dry up, but may persist for a long time after the eye has become white.

In a personal observation we have seen them even on the lachrymal caruncle.

The granulations of **trachoma** are visible with the microscope under the form of clear areas. According to Gallemaerts, if we instil a 4 per cent. solution of methylene blue or violet or neutral blue, we see, standing out from the rest of the conjunctiva, groups of cells, stained blue, and forming small eminences containing fine capillaries.

Several authors class these formations as *tuberculides.* Microscopic characters which would allow of a classification of the various forms of conjunctivitis have not yet been described. Moreover, when the globe is considerably injected, examination of a great part of the conjunctiva presents great difficulty and is, on the whole, of little interest.

CHAPTER V

THE CORNEA

SPECIAL TECHNIQUE

All the methods of illumination may be used for the cornea, which is easy to examine.

Oblique illumination will serve for a general survey. The reflex from the anterior surface may easily be avoided by the following procedure :—

(*a*) The beam strikes the cornea at a *small angle of incidence*, that is to say, almost perpendicularly. The axis of the microscope is placed obliquely so that the observer has both the incident and the reflected beams either on his right or on his left (*cf.* Fig. 18).

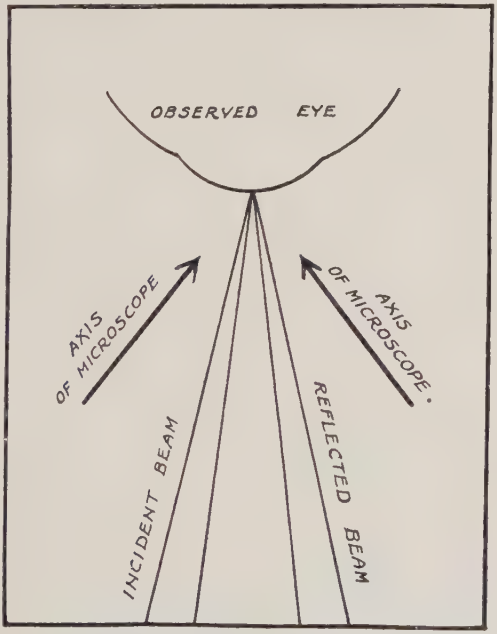

Fig. 18.—Diagram showing a way of avoiding the corneal reflex. The axis of the microscope makes a greater incidence than the luminous rays.

(*b*) The beam strikes the cornea at a *wide angle*. The axis of the microscope is directed almost normally to the corneal surface. In this case the observer has the incident beam on one side and the reflected

beam on the other. This is a more practical method than the first, and will usually be employed (*cf.* Fig. 19).

In practice it is better to vary the direction of the patient's gaze and that of the beam of light rather than to change the axis of the microscope, which will be moved only when absolutely necessary. In principle, the axis of the microscope is pointed directly forwards.

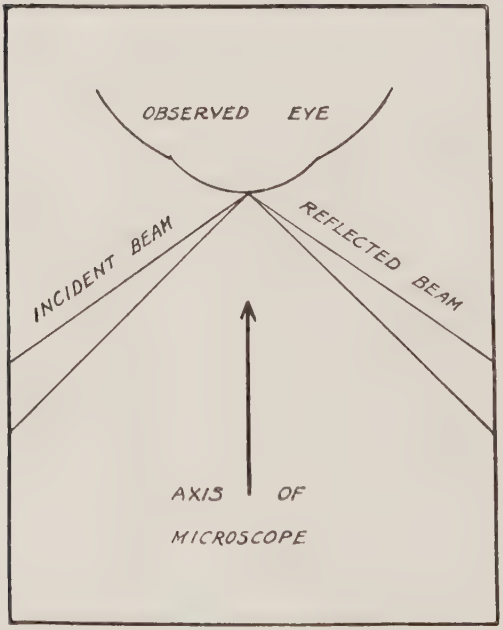

FIG. 19.—Diagram showing another method of avoiding the corneal reflex. The luminous rays have a greater incidence than the axis of the microscope. This method of procedure is the more practical.

The cornea is examined by *transillumination* by projecting the beam in such a way that part of the light is reflected by the underlying planes (lens, iris). When the lens is clear it reflects very little light. It is otherwise in the case of a cataractous lens. The iris, whatever its degree of pigmentation, is always a good *reflecting screen*.

When a part of the cornea is examined by transmitted light, *the microscope being, of course, focussed on this part*, the configuration of the iris is no longer seen, but the reflected light is coloured according to the colour of the iris. Objects are, moreover, different in colour when seen by transmitted light and by oblique light. These facts must be taken into account when forming an opinion as to the colour of any lesion.

Transillumination enables us to see remains of vessels in

the cornea very clearly, but their appearance differs from that seen by focal illumination. Bedewing, both endothelial and epithelial, is only clearly seen by transmitted light. On the contrary, certain other changes are more striking if examined in the zones of specular reflection (folds in structureless membranes, etc.).

If the axis of the microscope is in the direction of the rays reflected by the illuminating screen, objects under examination will appear *dark on a light background*, the colour of which will depend upon the colour of the screen. In certain circumstances the cornea may, however, be illuminated by oblique rays which do not enter the microscope. This constitutes examination upon a *dark ground*, a method which is of little more than theoretical interest.

The method of examination in *zones of specular reflection* finds its greatest application in the cornea. *Epithelial bedewing*, which looks like a carpet of droplets by transillumination, when examined in the zone of specular reflection, has a pricked appearance, which is very pronounced in secondary or subacute glaucoma. The edges of the zone are no longer sharp. The corners of the rectangle have a nibbled appearance. The blinking of the eyelids, carrying the tears over the little irregularities, momentarily obliterates them. The changes in the corneal epithelium caused by the instillation of cocaine or of holocain present a rather similar appearance.

On the posterior surface of the cornea, in the zone of specular reflection, will be seen the hexagonal cells of the endothelium. The technique is rather delicate. *The incidence of the luminous rays should be wide.* For finding the endothelium, the beam should illuminate the cornea near the limbus, and should be accurately focussed on its posterior surface. Here the zone of specular reflection exhibits a yellowish colour. The microscope will be focussed on this point. It is difficult to prevent at least a part of the reflex from the anterior surface of the cornea coming into the visual field, and one must guard against fixing this, or allowing it to distract attention from the posterior zone of specular reflection. In order to see the out-

lines of the endothelial cells well a fairly high magnification is necessary (*a* 3, oc. 2 or oc. 4 : *cf.* Fig. 20).

The reflexes, frequently double, given by folds in structureless membranes, may also be regarded as zones of specular reflection indistinguishable from catoptric images, in view of the high degree of curvature of the reflecting surfaces.

A *narrow beam* ($\frac{1}{4}$ mm. slit) is very useful for determining *the depth of any point within the cornea.* A metallic particle is embedded obliquely in the cornea. How deep is it ? The narrow beam is directed perpendicularly to the plane of the metallic fragment, and this is gradually approached. If, at the instant when the deep extremity of the foreign body is first illuminated, the thin posterior band is seen to have already passed it, we shall know that the foreign body has not penetrated to the deep surface of the cornea. If, at this instant, the posterior band has just reached the deep extremity of the foreign body, then the latter must have penetrated to the posterior surface of the cornea. If a wide beam is used, only one of the lateral faces of the corneal parallelepiped need be considered (*cf.* Fig. 9).

THE NORMAL CORNEA

Orientation.—As we have seen above, in the normal state, and still more in pathological conditions, the cornea reflects an appreciable amount of light. To the light reflected by the surfaces is added that which is scattered in its interior and which contributes to the visibility of this membrane. So that, if the beam has been focussed exactly on the posterior surface of the cornea, the part illuminated stands out rather brightly from the background, which remains dark. The illuminated part takes the form of a parallelepiped whose vertical edges will be curved, it is true, the anterior not being strictly parallel to the posterior on account of the difference between the radii of curvature of the surfaces of the cornea. The anterior surface of the parallelepiped is called the *anterior band*, and the posterior surface the *posterior band.*

The **anterior band** of the cornea shows nothing of note except

in the zone of specular reflection. With a magnification of 23 and more, minute particles of mucus suspended in the thin film of tears are seen very well. With the movements of the eyes, and still more with the blinking of the lids, the whole film is set into motion and the particles, carried downwards, rise again rapidly to a certain height, as if drawn by the upper lid, and remain in a state of unstable equilibrium. A flow of tears from the lachrymal gland to the lachrymal sac is not clearly seen. This arises from the fact that with high magnifications only a narrow section of the surface, which is tangential to the globe only over a small extent, is in focus, or from the fact that the flow is only established at the instant of blinking.

The film of tears, which contains, as well as particles of mucus, little bubbles of air and the products of secretion of the Meibomian glands, produces phenomena of interference with decomposition of light in the zone of specular reflection. Thus a transient and coloured mosaic is seen.

At the edge of the upper lid, and still better at the lower, the prismatic form of the film of tears can be made out. This prismatic form confers upon it optical properties (deviation of light rays), which on superficial examination might be attributed to the cornea. In the examination of the limbus below, it is advisable to draw the lid away from the globe.

The structure of the corneal **stroma** is studied on the sagittal surface of the parallelepiped nearest the observer, which is called the *optical section*. In it is seen a fairly regularly marbled appearance, which is difficult to describe. Contrary to what might be expected, the lamellar structure of the corneal parenchyma is not clearly brought out. Koeppe, however, claims to be able to distinguish a lamellar system from a lacunar one. In any case, it is certain that the deep layers of the cornea are identical with the superficial. The whitish parts of the granite-like design of the corneal substance are called by some authors "arachnoid corpuscles." Here, also, we make reservations.

In the normal state the cornea shows no vessels, except at the limbus.

The **nerves** are visible. They start from the limbus, their trunks having at first a radial direction. Numerous in the middle layers of the cornea, they are not rare in the superficial layers, but are absent from the deep layers. They look like fine bands or *silky filaments whiter than the stroma.* With a high angle of incidence of the beam and with the light projected on to them at their emergence from the limbus, they may appear to glitter. The same nerve keeps almost strictly to the same corneal layer. The nerve trunk branches dichotomously, the two branches containing between them an angle of 30° to 60° and being possibly unequal in length. Trichotomous branching is sometimes seen, as also is a further subdivision of the branches. Sometimes a whitish nodular corpuscle is seen at the point of subdivision, and the angle here may appear to be webbed. The nerve loses its myelin sheath at the limbus, but may retain it in exceptional cases. Anastomoses are never seen. The number of thirty nerve trunks given by Attias and Koeppe for the whole cornea would seem to be a minimum.

FIG. 20.—Diagram representing the corneal parallelepiped which the luminous beam cuts in the cornea. *zm, ba,* zone of specular reflection of the anterior band. In the zone of specular reflection of the posterior band (*bp*) is seen the mosaic of the endothelium.

The **posterior band** of the cornea appears as a smooth surface, reflecting, however, less light than the anterior, the difference between the refractive index of the cornea and that of the air being greater than that between the refractive indices of the cornea and aqueous humour. Theoretically, the fact must

also be taken into account that part of the reflected light is again sent back into the eye at the surface of the cornea.

To see the *endothelium of Descemet's membrane* (*cf.* Fig. 20), the zone of specular reflection must be focussed. The beginner will first examine the cornea near the limbus, the observed eye looking inwards with the light falling on it at a wide angle of incidence. If he avoids as far as possible the reflex from the anterior surface of the cornea and focusses the slightly yellowish posterior zone of specular reflection, then with a sufficiently high magnification (twenty-three to thirty-five times at least), he will see the cells themselves. These cells have well-defined outlines, which appear dark ; they are usually hexagonal in shape, sometimes pentagonal, occasionally square. The cell-layer has a honeycombed appearance. The nuclei of the cells are not clearly visible in man, but they are seen in the ox and the pig.

Towards the edge of the cornea the endothelium shows a surface which is *slightly embossed*. The depressions appear dark and may easily be taken for holes. Vogt has identified these formations with the " Hassal-Henle bodies," which these authors have described in the cadaver. These bodies, which are found especially in adults and old people, must not be confused with the round black spots caused by the interception of light rays by particles of mucus which may happen to be *on* the cornea, and which, not being in focus, give rise to circles of diffusion.

The **structureless membrane of Descemet** is not visible in the normal state. It will be seen later that in pathological conditions *it is frequently folded*, so that it gives characteristic reflexes, indicating the involvement of the deep layers following either inflammation or trauma.

Cellular deposits are sometimes seen on the posterior surface of the cornea in adolescents. These will be studied in detail in the chapter on the anterior chamber, as they are carried by the flow of aqueous humour.

The **sclero-conjunctival limbus** presents a less well-defined limit to the microscope than to the naked eye. Whitish radial

fibrous tracts arising from the sclera encroach more or less upon the cornea, their development varying with the individual. These tracts occupy a peripheral zone (*palisade zone*).

The **vessels** form a fine freely anastomosing network at the limbus. They may be brought out by rubbing the eye gently through the upper or lower lid. In the palisade zone the vessels also have a radial distribution and their fine anastomoses extend in fairly regular arcades to the edge of this zone.

CONGENITAL ANOMALIES

Koeppe has reported a **congenital diminution of transparency** in eight young people. Diffuse reflection of light was increased in all layers equally. Both epithelium and endothelium were normal. There was no evidence of an inflammatory origin.

In **microcornea** there are no changes in Descemet's membrane.

Under the name of **flat cornea,** Friede has differentiated a bilateral affection previously associated with microcornea. The cornea has the same curvature as the sclera, and is very small, because the sclera encroaches on it. The corneal refraction is, on an average, 28 to 29 dioptres, the total refraction being 7 to 9 dioptres. The globe is of average size. Microscopically this author has observed that the grey points in the corneal substance are considerably more numerous than usual. He does not give the absolute thickness of the cornea, but there appears to him to be no thickening towards the limbus, as is normally the case.

If (with Stähli, Kesterbaum, etc.) we accept **megalocornea** as a distinct entity apart from buphthalmos, we must expect to find, in addition to the hereditary factor which, in spite of Kesterbaum's assertion to the contrary, is also present in buphthalmos, a normal refraction or an astigmatism following the rule, absence of glaucomatous symptoms and of streaks in Descemet's membrane. The presence of an *embryontoxon* must also be added as a symptom of megalocornea. But it seems that authors give this name to conditions which are not identical. In megalocornea, iridodonesis is almost always noted, and luxations of the lens are not uncommon. It must be mentioned,

also, that, according to Kayser, megalocornea will be transmitted as a *recessive sex-linked character*, so that the anomaly is much more frequent in men than in women. Grönholm recognises the same mode of heredity (matriarcal heredity). In three generations of a family studied by this last author, thirteen persons, eleven of whom were males, were affected. In every case the corneo-scleral junction was well defined, the cornea globular and absolutely clear, the anterior chamber very deep and the iridodonesis so pronounced as to be obvious from a distance.

Most authors, Kayser, Reis, Salmon, Grönholm, are agreed on one point : in megalocornea alone this membrane is excessively thick, while the rest of the globe is of average size.

The cornea in **hydrophthalmos** usually shows *tears in Descemet's membrane*, which have the same appearance as those in keratoconus, but are generally more extensive and more easily seen. The borders of the tears are more or less hazy (*Haab's bands*).

In the advanced stages we see epithelial bedewing and opacification of the cornea going on to total leucoma.

The origin of hydrophthalmos is still under discussion. In a family of rabbits bred by Vogt, it seemed to be transmitted as a recessive character. In one eye of a buphthalmic rabbit examined by Rochon-Duvigneaud, obliteration of the reticular tissue which bounds the filtration angle was evident. We have seen in a pig on one side a microphthalmic eye weighing less than 3 grams, and on the other a buphthalmic eye weighing 22 grams. The walls of the buphthalmic eye appeared distended and thinned to the naked eye. The place of the lens was taken by a flattened fibrous sac. The atrophic iris was in contact with the posterior surface of the cornea.

SENILE MODIFICATIONS

According to Vogt, the first senile change in the cornea is an *increase of internal reflection* at Descemet's membrane, towards the periphery. This phenomenon is sometimes observed at as early an age as twenty to thirty years. We know that the

arcus senilis is separated from the limbus by a clear space. Now, under the microscope, it is seen that this transparency does not extend to Descemet's membrane, but that the opacity of the arcus senilis is continuous to the limbus in the deep layers. Vogt has pointed out the presence of dark intracorneal lines in the arcus senilis.

The **Hassal-Henle bodies** are seen in the living eye as *dark rounded plaques on a light background*, resembling holes in the endothelium when examined in the zone of specular reflection. As these structures project into the anterior chamber they are caught by the light at a different angle from the surrounding structures and do not therefore appear to glitter. They are best seen in the peripheral parts of the cornea. According to Vogt, the changes described by Koeppe under the name of "congenital pitting" are no other than the Hassal-Henle bodies.

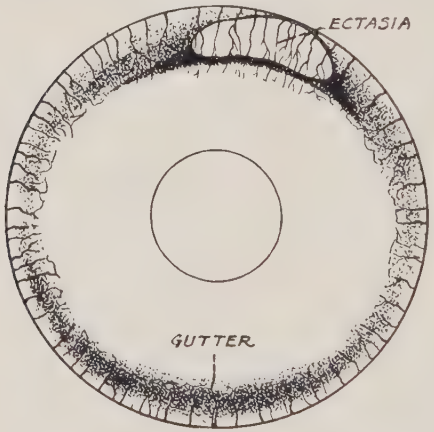

Fig. 21.—Marginal degeneration of the cornea. The opacity takes the form of a ring and is most marked above and below. Everywhere a fine new formation of vessels extends beyond it towards the centre of the cornea. Below, the stage of the gutter; above, stage of ectasia.

According to Vogt, the diameter of these bodies in a man of fifty-five years was from 0·07 to 0·08 mm. Often several verrucosities became confluent, making larger ones. These bodies, which are constantly present in adults, should be included under senile changes.

Ectatic marginal degeneration of the cornea presents a very interesting picture. Under the microscope, the changes are seen to be of three sorts: *Peripheral vascularisation of the cornea, opacity resembling arcus senilis, and thinning of the peripheral zone of the cornea at first gutter-like, later ectatic.* The

vessels have a radial trunk and anastomose towards the centre of the cornea. They extend a little beyond the zone of opacity. Finally, the opaque zone becomes circular by fusion of the two arcs. The opacity is composed of amorphous points, very fine, yellowish in colour, especially dense in the immediate neighbourhood of the endothelium and most marked not at the limbus but at a little distance from it (*cf.* Figs. 21 and 22). Wherever it is opaque the cornea is thinned. In more advanced cases, a

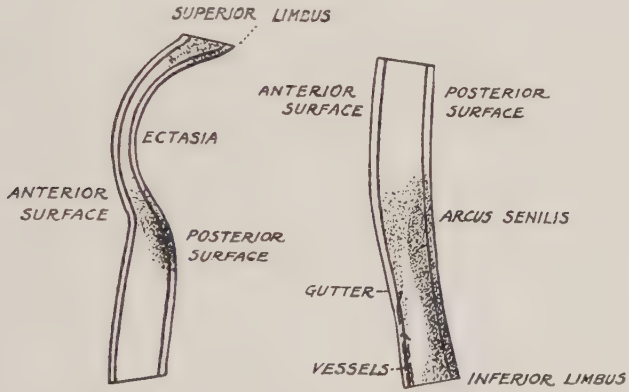

FIG. 22.—Marginal degeneration of the cornea. To the left an optical section showing the distribution of the opacity and of the ectasia (upper part of the cornea). To the right an optical section showing the gutter, the opacity and the newly-formed vessels (lower part).

pellucid ectasia is seen above, while below, the groove still persists. It would appear that there is first thinning, then furrowing, then ectasia. An astigmatism against the rule is produced by the flattening of the cornea in its vertical meridian and may measure 9 D (pers. obs.) or even more (Terrien, Seefelder, etc.). The lesions are bilateral but not equally marked. According to the published cases, it would seem that the right eye has a special tendency to undergo marginal degeneration.

Vogt has reported in old people an excessive formation of verrucosities occupying not only the periphery, as is the rule, but also the *axial parts* of the cornea. It gives the impression

of a layer of spray fringing the posterior zone of specular reflection. The frequent presence of pigment on the posterior surface of the cornea further complicates the appearance of these modifications, which, moreover, present a different picture according as they are examined by focal illumination or by transillumination.

Deposits of **crystals** *in the corneal parenchyma* as a senile manifestation must be extremely rare. Vogt has seen them in a woman of seventy, in one eye only. There was a well-marked arcus senilis, in the opacity of which angular or needle-shaped crystals shone red and green (cholesterin ?).

The pigmented line *of Stähli* will be described under pathological changes.

TRAUMATIC LESIONS

The slit-lamp can very well be employed in the examination of **foreign bodies** in the cornea and enables us to determine their position exactly as shown above. The foreign body is always examined in the side of the corneal parallelepiped turned towards the observer, and its distance from the anterior band of the cornea indicates its relative depth. A foreign body situated in the parenchyma may result in the formation of *folds in Bowman's membrane.* These must not be confused with folds in Descemet's membrane, which are much deeper. If the foreign body is not extracted, folds may appear also in Descemet's membrane.

A **contusion of the globe,** however slight, causes folds and liberates pigment which becomes fixed on the posterior surface of the cornea and can still be found long after the accident. The vitreous would show pigmented opacities, and examination by *red-free* ophthalmoscopy would reveal folds in the superficial layers of the retina.

In **lime-burns,** the cornea is finely shagreened. White lines, 1 to 2 mm. long and fairly superficial, possibly lesions of Bowman's membrane, cross it in all directions and remain visible for several months. The accompanying folds of Descemet's membrane disappear more quickly (pers. obs.).

Rumbaur describes a rather different picture, a multitude of small bright points in the part of the cornea affected. This zone was separated from the healthy cornea by needle-shaped crystalline deposits which appeared to be calcium phosphate.

In the classical **burn with a curling iron** it is seen that the eschar impressed, easily visible to the naked eye, is bounded by rounded lines. Within these is seen a complicated network of sinuous lines, showing blisters below. This appearance is quite characteristic (pers. obs.).

Perforating wounds of the cornea always cause the formation of folds in the structureless membranes. Folds in Bowman's membrane are comparatively less frequent and less marked than those in Descemet's membrane. To differentiate the one from the other a sharply focussed beam will be used.

In a burn due to " mustard " gas in an officer, Pesme observed the late development of a corneal fistula. The cornea showed opaque specks which reduced the visual acuity to $\frac{6}{18}$. The track of the fistula was marked by a series of vesicles, the most anterior of which were raised above the corneal surface. There were also folds in Descemet's membrane. The fistula healed after galvano-cauterisation.

It is not unusual to see **tears in Descemet's membrane,** the edges of which have become rolled on themselves and float in the anterior chamber. It is not necessary to use a high magnification to see this clear membrane, the detached parts of which give rise to reflexes varying with the particular wound.

Among traumatic lesions **intracorneal hæmorrhage** must also be mentioned. Exceptionally, we have also seen it following a keratitis with infiltration. The subjects are always elderly people. The blood pigment, diffusing around the hæmorrhage, produces a yellowish halo. According to Koeppe, the coloration marks out the lacunar system first, and later the lamellar system. There would also be extensive vascularisation of the limbus in the deeper layers.

In a patient of sixty-five, who had been working with **silver dust** for fifty-one years, and whose vision was not appreciably reduced, there was observed a greyish haze in the deep layers

of the cornea caused by a dense network of lines intersecting in all directions and situated in Descemet's membrane or immediately in front of it. The endothelium had remained normal (Subal).

In **siderosis** of the globe the cornea is stained yellow, and this can be seen in the section. With a sufficiently high magnification, it is seen that those points which are usually greyish, are more especially tinted yellow. The coloration is deeper at the limbus than near the centre.

When there is a metallic foreign body with **copper** base in the eye, it may be seen, after several months, that the cornea is impregnated with copper. *The seat of the coloration is in Descemet's membrane, and it begins exactly at the limbus, where it is most intense.* It gradually fades away towards the middle of the cornea. It begins at the limbus either above or below. It may form a continuous ring thicker above than laterally (Jess, etc.). This ring is analogous to that of Fleischer, which we shall study later. Its topography is the same in every case.

PATHOLOGICAL CHANGES

Thinnings and **thickenings** can be shown by the slit-lamp. It is advantageous to use the narrowest beam. Modification in thickness of the cornea will be observed on moving the beam backwards and forwards across the cornea and watching the luminous *section*. Moreover, such modifications will be more appreciable the more localised they are.

Thickening is always, as far as we have seen up to the present, the result of inflammatory processes in the cornea. It is caused by a cellular or serous infiltration. According to the situation of the inflammatory focus, the cornea bulges either anteriorly or posteriorly. A marked thickening of the peripheral and lower parts of the cornea is often seen in patients suffering from prolonged irido-cyclitis. Sometimes the thickening does not extend to the limbus, but begins at some distance from it. In disciform keratitis thickening of the central part of the cornea is seen. This thickening not only shows itself in the optical

section, but causes also a characteristic *annular reflex*, to which Vogt has called attention. The cornea, forming a protuberance behind, limited annularly by a surface acting as a convex mirror in front, the reflex is found a little behind the cornea in the anterior chamber. In all cases of interstitial keratitis there is thickening of the cornea, which is shown in clearer relief the more localised it is.

Thinning is produced by ulcerative and cicatricial processes in the cornea and most often occurs at the expense of the anterior surface of the cornea. It is seen especially after suppurative keratitis in old people. It must be mentioned, however, as pointed out by Lüssi, that by no means all thinnings of the cornea are followed by ectasia of the thin area. We shall study later the phenomena produced by keratoconus.

In the cases long known as " œdema of the cornea," the slit-lamp allows us to differentiate at least two phenomena, one of which involves the epithelial layer and the other the endothelial layer.

Bedewing of the epithelium is characterised by the formation on the surface of the cornea of multiple rounded protuberances arising from swelling and probably also from fusion of epithelial cells. Moreover, these processes are not limited to the superficial cellular layer, but involve the rest. This bedewing is observed in two ways, either by transillumination or in the zone of specular reflection.

The microscope being focussed on the anterior band of the cornea, the beam is projected in such a way that the light reflected by the iris falls upon the part of the cornea under observation. Whereas, in the normal state the cornea appears absolutely transparent under these conditions, when there is epithelial bedewing, the appearance is that of glass which has lost a little of its polish and is more or less regularly grained. This appearance is particularly marked in glaucoma and is also seen round wounds and foreign bodies in the cornea and in inflammatory conditions.

In normal individuals there is a fine bedewing quite near the limbus which is not pathological and with which we should

familiarise ourselves before passing to the examination of pathological cases.

When there is epithelial bedewing the anterior zone of specular reflection is less well defined than normally, and its edges are more or less rounded. The light is seen to be reflected more or less irregularly by a multitude of tiny protuberances. The less the cornea is moistened by the tears the more easily visible this appearance becomes. Also, when blinking moistens it afresh, the irregularities undergo a transitory eclipse, but reappear in a moment. This phenomenon has been misinterpreted by some authors to mean that the heat from the beam causes the tiny " bullæ " of the bedewing to disappear.

Endothelial bedewing is seen by transillumination. In uveal inflammations, if one focusses the posterior band in the cornea and directs the beam in such a way that the light reflected by the iris or lens illuminates the part under examination, one sees, even with low magnifications, that the posterior surface seems to be covered by a fine spray. This spray usually extends over the whole cornea, but there are exceptions. The bedewing may, for example, be localised round the scar of a perforating wound.

At the onset of iritis there are sometimes formed characteristic *islets* which appear suddenly, and upon which deposits and precipitations occur later. It must be noted that these islets are not confined to the triangular area base downwards which is the special site of precipitates, and that at the beginning they show not a trace of pigmentation.

Epithelial and endothelial bedewing may co-exist. This is the case in grave conditions : irido-cyclitis, etc. It is sometimes very difficult to distinguish the two phenomena. The method is one of exclusion. First the anterior zone of specular reflection is examined to determine whether the epithelium shows bedewing. Then the corneal parallelepiped is sharply focussed, and by focussing the microscope, using high magnification, it is possible to discover whether the endothelium also exhibits bedewing.

It is probable that in these phenomena œdematous swelling of the epithelial or endothelial cells is the initial change.

Endothelial bedewing is finer and more regular than epithelial. The former is usually complicated by precipitates of fibrin, cells, etc., which are only visible at first with high magnifications. Deposits are particularly well seen in the posterior zone of specular reflection, where, interfering with the specular reflection, they appear black. Simple bedewing of the endothelium focussed in the zone of specular reflection, causes effacement of the edges of the cells, which appear amorphous. There is also sometimes an iridescence in the zone of specular reflection. This may also be associated with old irido-cyclitis.

The endothelium provides a very sensitive index and its examination allows a very early recognition of uveal affections, as has been well shown by Vogt and Schnyder.

True epithelial **bullæ** are rare. They should not be regarded as a constant feature of keratitis. They are observed in certain scrofulous forms, where they break down rapidly, giving place to a superficial infiltration. In degenerated corneæ they are much more stable. They are also characteristic of the epithelial dystrophy of the cornea of Fuchs.

The bullæ are not likely to escape the observer. If they are large enough and in relief, and if the narrow beam is projected on them exactly, it is seen that the anterior band bulges forwards. We notice also the presence of a *tiny reflex* from the anterior surface to which may be added a second reflex from the posterior concave surface. Another phenomenon is also common to bullæ : as they reflect more light than the surroundings, the parts behind them will be less illuminated, and will appear darker. That is to say, *there will be a trail of shadow behind each bulla.*

Vacuoles of the lens present these same phenomena, as well as the globular cells of Elschnig.

Processes of *liquefaction* localised in the epithelium may present a globular appearance which it is important to distinguish from bullæ. We have shown, with J. L. Burckhardt, that if the cornea of the rabbit be inoculated with antivariola vaccine, or with variola virus, localised round patches of infiltration appear after some hours. Then the foci break down in

crater-like fashion (oblique illumination). On examining a focus by transmitted light it is seen that it distorts the configuration of the iris, as a tiny lens or a glass ball would. There is undoubtedly a liquefaction of the cells. Paul had already described these vesicles, verified more recently by examination *in vitro*, and based on their presence a method of diagnosis of variola. He produced vesicles in the enucleated eye by treating it with an alcoholic solution of sublimate. The slit-lamp enables their development to be studied in the early stages on the living animal.

Similar changes are produced by the virus of herpes febrilis, but the incubation period is longer and the foci show a greater tendency to become confluent. Possibly other *skin eruptions* (Levaditi), behave similarly with regard to the cornea. Personal experiments with the virus of varicella, too few in number, have given negative results.

Fine opacities, *well defined and permanent*, situated in the deep layer of the epithelium or at the level of Bowman's membrane, are very rare.

A patient of Erggelet's, sixty-eight years old, with cataract, showed a multitude of tiny white points over almost the whole of the cornea.

A young girl of eighteen showed a fine scratch-like opacity in the right eye. It was situated "down and out" at 2 mm. from, and more or less parallel to the limbus. The upper line of the opacity was absolutely sharp, but below, the dense white line sent tiny isolated or confluent points towards the limbus. The whole line was 4 mm. long. On examining the cornea in the section of the beam, a zone of discontinuity was seen beginning at the limbus and extending a little beyond the line towards the centre. There were also very fine vessels with blood corpuscles coming from the limbus. The history was absolutely negative. The condition appears to be stationary (pers. obs.).

In another patient of thirty-one, the opacity was situated at the centre of the cornea in the region of Bowman's membrane and assumed the form of a horseshoe. It was also composed of

small, quite white points. There were no symptoms of inflammation (pers. obs.). The appearance recalled strongly a picture of Kraupa's designated "calcareous infiltration" of an opacity. We do not know on what this author founded his diagnosis.

In inflammation, the *corneal stroma* often suffers a loss of transparency such that by oblique illumination it appears more milky than normally. It does not seem possible to distinguish the opacities of the lamellar system from those of the lacunar system, as Koeppe has done.

It is observed in keratitis that the opacity is not homogeneous, but affects unequally different layers of the cornea which sometimes takes on an appearance which Duverger and Lampert would prefer to name "*état en glaçon*" so as not to prejudice its anatomical basis. Several authors have described a formation of *folds* and of *false folds* in the substance of the cornea. But there are no false folds, and true folds should be recognised as such by a careful examination. On examining the cornea in the clearly cut parallelepiped which the focussed beam marks out, it is found that the folds belong most frequently to Descemet's membrane (*vide infra*). There may be in the parenchyma, however, opacities or infiltrations which may extend either obliquely or concentrically to the surfaces of the cornea. But these phenomena are not very common.

Infiltration of the cornea causes thickening of this membrane. The cornea then bulges either into the anterior chamber or forwards, according to the position of the patches. Later, definite thinning may be seen to occur. Deep infiltrations are often associated with precipitates on Descemet's membrane. These precipitates are localised exactly behind the infiltration and have escaped notice until now.

The infiltration of **acne** is almost always horseshoe or tongue-shaped (Lopez-Lacarrère). As is known, vascularisation is always very pronounced. In some other infiltrated ulcers as, for example, in the *keratitis of reapers*, the slit-lamp in experienced hands gives us exact information not only on the superficial changes, but also as to the depths to which the infiltration

has extended. For this a narrow and well focussed beam must be used.

The microscope does not lend itself especially well to the study of **corneal opacities.** The high magnification makes their edges less clear. The beginner will often ask himself why the iris appears dull and will struggle in vain to focus it sharply, when corneal opacities have escaped his notice. For this reason examination by focal illumination with and without the loupe should always precede microscopic examination. Although diffuse nebulæ are difficult to focus, it is true that dense localised opacities can easily be studied with the microscope, especially with regard to their depth.

Vascular changes in the cornea can be studied easily.

New vessels may give rise to sinuous reflexes, by raising the epithelium, if they are large enough and superficially situated. Even if there is no regular reflex the vessel wall reflects enough light to appear whitish in examination with focal illumination. Owing to this reflection, the red colour of the blood is not clearly seen. Seen by transmitted light, on the contrary, the vessels have a reddish colour which may become bright red if they carry a blood stream. As, in certain conditions, it may be difficult to differentiate between a nerve trunk and a vessel, two methods of examination will always be employed.

With the slit-lamp it is easy to see whether the vessels under examination are superficial or deep. Deep vessels are frequently seen to exhibit a mode of branching and a distribution described by authors as peculiar to superficial vessels. This arises from the fact that with the naked eye, on the whole, only the larger vessels, which are actually radial in direction, are seen.

Vessels in corneal opacities are easily seen by contrast. They often present constrictions and dilatations, which afford the best place for a study of the circulation. In ideal conditions a low magnification suffices for this examination. We have often been able to show that, with a magnification of 10 diameters, groups of blood corpuscles can be seen, if not individual ones.

Obliterated or merely **shrunken vessels** show as greyish bands.

Often gentle massage of the globe will render permeable a vessel which appeared quite atrophic and will show that the obliteration is not permanent. In relapsing affections it is probable that such vessels, again rendered permeable by the inflammation, appear to the naked eye as newly formed vessels.

As the vessels allow less light to pass than the corneal stroma, it may happen, if they are superficial, that they cast a projected shadow on the posterior surface of the cornea. A network of dark lines is then seen in the posterior band. This is the case, for example, in marginal degeneration of the cornea, where, as we have shown, the vessels are well developed.

According to Kreiker, invasion of the cornea by vessels takes place only exceptionally by branching, but rather in the following way: loops make their way slowly towards the centre of the cornea, and, when two loops meet, an anastomosis occurs.

Most inflammatory conditions make the **corneal nerves** more visible. Certain affections are invariably accompanied by nerve changes, as, for example, herpes. In one observation by Verderame, in which there was active syphilis, the thickened nerves were visible to the naked eye for several days. There was also irido-cyclitis in this patient, who was thirty-nine years old.

In irido-cyclitis of long duration the **posterior layers** of the cornea sometimes become opaque.

In a young girl who had suffered from tuberculous irido-cyclitis for several years, the deeper layers of the cornea showed an opacity which was most marked in the lower third and suggestive of an arcus senilis. But the opacity was more extensive and deeper than is the case in arcus senilis and was easily distinguished from it (pers. obs.).

A similar opacity is sometimes observed also after interstitial keratitis.

It seems that there are deposits in the lowest parts of the cornea at the very onset. Descemet's membrane and then the deep layers of the parenchyma are involved soon afterwards.

The two **structureless membranes** of the cornea may, by

reason of folds, give rise to characteristic reflexes which are frequently double.

That of Bowman hardly ever becomes folded unless there is a foreign body embedded in the cornea or a perforation. Usually, when Bowman's membrane is folded Descemet's is also.

Folds in Descemet's membrane, at least those of traumatic origin, have long been known. They provide the anatomical foundation of the **striate keratitis** seen after extraction of the crystalline lens. After cataract extraction the folds are more or less perpendicular to the incision and may persist for some weeks, fading gradually. In perforations of the cornea the folds converge towards the perforation. They are often marked by *two parallel linear reflexes*, which are clearer the more localised the illumination, and which join and fuse at the extremities of the fold. The interval between the twin reflexes depends, as Vogt has shown (*vide supra*, p. 53), on the angle of observation and on the incidence of the illuminating beam. In all cases of deep keratitis more or less brilliant and sinuous reflexes are seen at the level of Descemet's membrane. The *dark bands*, which are sometimes superposed on the reflexes, are produced, according to Vogt, by the same reflecting surface. They cut the reflexes more or less perpendicularly. If the endothelium is focussed in the zone of specular reflection it is seen to be crossed by these dark lines, which shows that they belong to Descemet's membrane.

Reflexes which are clearly seen by focal illumination may be invisible by transillumination, if the reflecting surface is not opaque. On the contrary, they are most often seen as rather dark slender bands, the two reflexes fusing to form a single band.

A peculiar change has been described by Stähli as following parenchymatous keratitis. It takes the form of **hyaline striæ**, apparently produced by a thickening of Descemet's membrane, which is sometimes considerable, protruding into the anterior chamber. These changes are sometimes so marked as to be discernible with a simple loupe, if a good focal illumination is used.

In certain cases (keratoconus) there are seen in the substance of the cornea, **very fine,** more or less luminous **striæ,** which are not caused by folding of the structureless membranes. They are finer than the reflexes from folds and not double like them. They are seen towards the summit of a conical cornea, are always multiple, almost parallel, and usually have a vertical or slightly oblique direction. Careful examination reveals the presence of anastomoses between the striæ. These *striæ of keratoconus* are very characteristic and are seen in corneæ which are still transparent. Sometimes there are several systems crossing and forming a lattice. They must not be confused with the opacities of keratoconus, which are whiter, more widespread and in the form of irregular bands. The two conditions are, moreover, both present in advanced cases of keratoconus and probably arise from processes related to atrophy.

Ruptures *of Descemet's membrane* are seen less frequently than simple folds. They are often noticed in keratoconus and in hydrophthalmos. Sometimes, when the keratome is being used, its point accidentally comes into contact with the posterior surface of the cornea, producing a tear with slight opacity of the deeper layers. These changes may escape notice in a superficial examination, more especially as the cornea becomes clear again later.

The width of the ruptures may be as much as 1 mm. Vogt notes, in a case of hydrophthalmos, a separation of the edges of 0·6 to 0·7 mm. The form of the rupture may resemble that of folds. Ruptures are, however, more sinuous, often crescentic. Their outlines are very clear, and if they provoke reflexes, these are almost stationary. The outlines always converge towards the two extremities, so that the rupture has the appearance of a leech. Descemet's membrane is sometimes rolled on itself at the edges of the rupture, and this gives rise to accessory reflexes which are more or less parallel.

Knowledge of **precipitates** has been considerably enriched by the slit-lamp. In microscopy the term precipitate should be applied to any deposit on the posterior surface of the cornea, whatever be its size. The most minute are only visible when

the zone of specular reflection of the endothelium is focussed. They appear then as black points which Vogt compares to the defects in the silvering of a mirror. The largest are, as we know, visible to the naked eye.

Precipitates are formed of red and white blood corpuscles and cells of neighbouring membranes, retinal or uveal pigment, sometimes even of lens fibres.

Two kinds of precipitates are found on the posterior surface of the cornea *in the normal state* :—

(*a*) Unpigmented cellular deposits.

(*b*) Pigment granules.

The **cellular deposits** are met with more especially in children, and are unstable. They are well seen, with a magnification of 37 diameters, either by transillumination, or by focal illumination. As these cells seem to be carried by the currents of the aqueous humour, we shall study them specially in the next chapter.

The **pigment granules** deposited on the posterior surface of the cornea are associated with senile changes. Möschler finds them in persons under twenty years of age in 11 per cent. of cases, from twenty to fifty years, in 22 per cent., over eighty years, *constantly*. These granules seem to be independent of the colour of the iris and come from the retinal pigment layer. They occupy particularly the lower triangle of the cornea. Some authors, following Koeppe, have suggested that this depigmentation of the iris was the expression of a glaucomatous state (*pre-glaucoma*). But this assertion has not been proved at all.

Pathological precipitates may be divided into two classes : pigmented and unpigmented. As a general rule, precipitates after a certain time become more or less pigmented. Only the precipitates of *heterochromia*, with degeneration of the globe, remain unpigmented.

Pigmented precipitates are distinguished by their size from pigment granules. They are more or less rounded. Very rarely they are stellate, as are also certain deposits on the anterior lens capsule. This stellate form indicates that they are old precipitates.

Unpigmented precipitates are seen at the onset of irido-cyclitis, sympathetic ophthalmia, etc. With a high magnification, it is observed by transillumination that they are composed of droplets which sometimes become confluent. According to Vogt, the endothelial cells are liable to become swollen, so as to take the form of droplets. According to Koeppe, these droplets are always deposited elements.

It is known that precipitates are deposited more especially on the lower part of the cornea, over an area triangular in shape, with apex upwards. This rule, however, is not without exception. We have seen above that corneal infiltration may be accompanied by precipitates confined to the region immediately behind them. Less frequently, in certain extremely insidious forms of irido-cyclitis, precipitates are seen to occupy an annular disc at the very centre of the cornea. In a case described by Vogt, which we have seen again since, such a disc of precipitates had disappeared, to reform and disappear again still later without there having been injection of the globe.

The micrometer eyepiece is required to observe the increase in size of a particular precipitate and to count the precipitates.

It is useless to describe in detail the many various appearances which precipitates may assume. Such details would be merely morphological, and would have no value from the point of view of the etiology of the various affections. Koeppe has described with an extraordinary wealth of detail all the precipitates which may be seen on the cornea, and has drawn etiological deductions which have not been confirmed. This author seems, moreover, to be unable to substantiate his early statements.

One appearance should, however, be known, because it is important from the point of view of prognosis. After irido-cyclitis precipitates are more or less resorbed, and the bedewing of the endothelium in its original form disappears. Meanwhile the detritus, particles of fibrin, etc., persist on the posterior surface of the cornea, and confer on it a certain *lack-lustre appearance*, which can only be seen by transillumination. It gives the impression of a deposit of minute shavings of a translucent substance.

During recent years several types of **pathological pigmentation** of the cornea have been described. Histological examinations have been made in some cases, but our views on the nature of certain pigments are still limited to hypothesis. These pigmentary changes are of great clinical interest, owing to the fact that they sometimes constitute an early symptom of a general affection.

When an old central corneal opacity in any adult is examined with a loupe and a very white light, such as that of the Auer

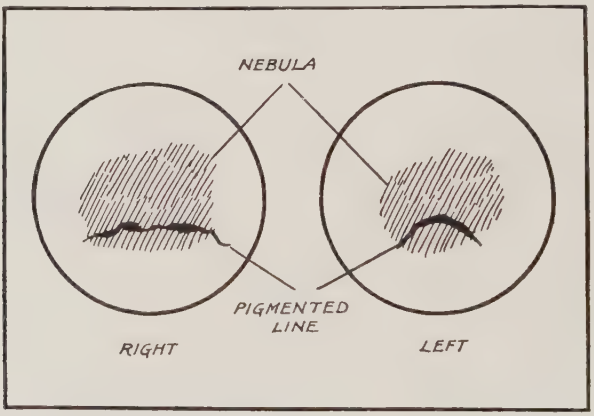

Fig. 23.—Relation of the pigmented line to the nebulæ. Diagram from life. Mme. C., forty years. R.V. : 0·3, not improved. L.V. : 0·3 M.3.

burner, a yellowish pigmentation of certain parts of the opacity is invariably seen. This coloration takes the form of a broken line of varying thickness, having a more or less horizontal direction and situated towards the middle of the interpalbebral space. It does not extend to the periphery of the cornea, perhaps by reason of the better nutrition there. Fig. 23 shows the appearance of this pigmented line. More rarely the pigment is disposed in spots which are more or less rounded or even annular.

Authors have expressed opinions as varied as they are ingenious on the nature of this pigmentation, but we shall not discuss them here.

Now Stähli, using a light source of great brilliance and a Hartnack loupe, described, in 1918, a brownish, pigmented line, which was sometimes to be seen in adults who had no corneal opacity.

The line is better seen with the Nitra lamp than with the Nernst, and better still with the small arc. It is situated superficially in the epithelium. Its length is on an average equal to half the diameter of the cornea. Directed more or less horizontally, it is sinuous and occasionally branched. Its width is 20 to 30 microns. Its colour is brownish yellow or greenish yellow. Vogt has seen it disappear after an operation for cataract ; he distinguishes a green, a yellow and a whitish type.

Grüninger has investigated its histological basis. But on the cadaver he has never succeeded in finding the pigment, which had possibly disappeared during the manipulations. He attributes the line of Stähli to *alterations*, which he has described, *at the level of Bowman's membrane :* lacunæ of the structureless layer and a collection of cells.

The nature of the pigment is still obscure. Stähli thinks that it is an alkaline hæmatin dissolved in the tears.

In the origin of the pigmented line a factor which seems to us to have a certain importance should not be neglected : the folding of the epithelium in the blinking and closing of the lids. Indeed, if an entoscopic apparatus, such as that of Darier, be used, it is seen that blinking, especially if energetic, provokes the formation of a fold in the epithelium, which may persist for a moment. It is possible that in this region Bowman's membrane finally undergoes changes which favour the deposition of pigment, the exact nature of which is as yet unknown.

Fleischer's ring, which is characteristic of conical cornea, is also of a brown colour. It takes the form of a line encircling the conical cornea. It may, however, be absent. Fleischer thinks that the pigment is not of ocular origin, as Augstein has thought, but is probably from hæmosiderin, giving a blue reaction with potassium ferrocyanide.

An observation of Meesmann seems to establish the depen-

dence of the pigmented ring on a *rupture in Bowman's membrane*. His subject, a woman of thirty-six, had conical cornea, with the usual characteristics, in both eyes. A fissure in Bowman's membrane was seen in the form of a white circular line, limiting the ring, which was very pronounced, and situated in the deep layers of the epithelium, internally.

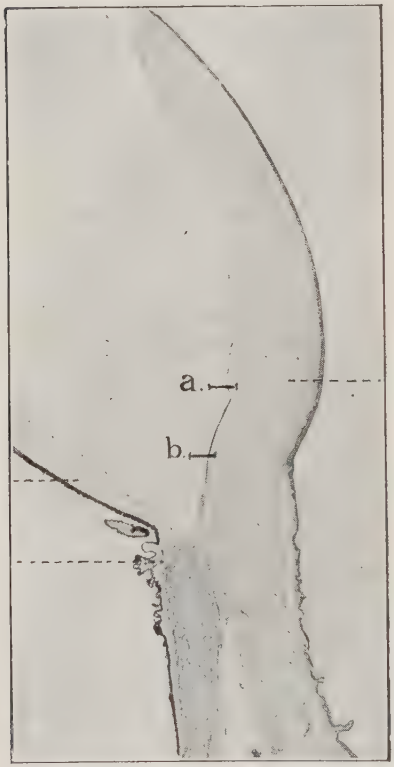

Fig. 24.—Pigmentation of the cornea in hepato-lenticular degeneration. General view. The pigmentation which is situated in Descemet's membrane extends from *a* to *b*. Magnification about × 10. Trioxy-ferrihæmatin of Hansen. (Photograph taken from Hall, *La dégénérescence hépato-lenticulaire*, Paris, Masson, 1921.)

Fleischer's ring should be distinguished from **that of pseudo-sclerosis,** which has a different situation. This was first described in 1902 by Kayser, who took it for a congenital anomaly. Fleischer found it to be a symptom of pseudo-sclerosis and of Wilson's disease, affections known collectively as *hepato-lenticular degeneration.*

In a histological observation by Hall: "The sections showed that the pigment was situated in Descemet's membrane immediately under the cubical endothelium which covers it. As was evident already from the examination of the living subject and as is clearly seen in Fig. 24, the pigmentation begins only at a little distance from the angle of the anterior chamber near the place where the endothelial layer is seen distinctly. The limit is here quite sharply marked, while the pigment diminishes gradu-

ally towards the centre of the cornea; altogether, the pigment is seen only over an area of about 1 mm. to 1·5 mm. It consists of fine granules, very dense, blackish brown and much finer than the pigment grains of the pigment epithelium of the retina. They are uniformly distributed immediately under the endothelial covering and do not always fill Descemet's membrane throughout its entire thickness; thus outside the pigment there may be seen sometimes a narrow zone free from pigment, where the usual homogeneous and structureless appearance of the membrane persists (Fig. 25). The pigment does not give the reaction for iron. . . ."

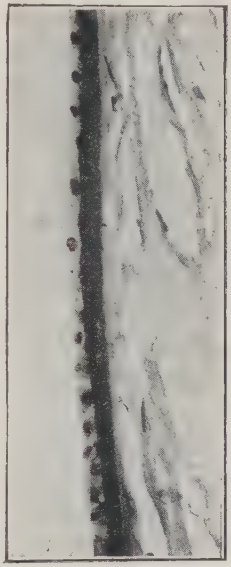

FIG. 25.—Pigmentation of the cornea in hepato-lenticular degeneration. The corneal pigment is situated in Descemet's membrane, immediately beneath the endothelial layer. Magnification about × 250. Neutral red. (Photograph taken from Hall, v., *supra*).

From the chemical point of view, the nature of the pigment has been studied by Fleischer and by Rumpel. Rumpel holds that it is a silver compound, while Fleischer is less positive. It is insoluble in ether, chloroform, alcohol, xylol, acids and alkalis, but it is soluble in a solution of ammonium sulphide. It does not give the Prussian blue reaction nor that of Gmelin, and is not decolorised by hydrogen peroxide. Hall compares it with malarial pigment and thinks that it is derived from hæmoglobin. Kubik, having observed with the spectroscope, in the living, that the pigment behaves like bilirubin, likens it to this substance. Metzger, however, with a patient of twenty years suffering from hepato-lenticular degeneration, who showed, as well as the ring, a coloration of the skin round the nail matrix, has used the spectroscopic method without obtaining clear results.

Hall attributes to the corneal pigmentation an absolutely pathognomomic significance in the diagnosis of pseudo-sclerosis

and Wilson's disease. Although it occurs in only half the cases of the Wilson type, it is present in all the cases of pseudo-sclerosis collected (sixteen in all).

An observation of Jendralski's confirms the diagnostic value of the ring. Of seven brothers and sisters four showed a typical ring. In the two eldest patients the symptoms of Wilson's disease were very pronounced. The brownish-green spots covered Descemet's membrane, giving it a scaly appearance. Denser towards the periphery, they seemed to be formed by the fusion of smaller rounded dots. Between the spots the membrane appears bright and granular. The author was able to make a histological examination which showed that the coloration extended to within 2 mm. of the centre of the cornea. It involved about a quarter of the thickness of the structureless membrane and ended fairly sharply towards the centre of the cornea. The hyaloid membrane of the choroid was intact.

It appears, however, that a similar ring may be found in cases other than those of hepato-lenticular degeneration, as an observation by Kraupa shows. His subject, fourteen years old, had no changes in the nervous system, but had a swollen and indurated liver. There was seen in each cornea a *greenish* ring, impregnating the endothelium with dots of different sizes and giving it a metallic appearance. The endothelium showed lacunæ in places (?).

German authors (Kruckenberg, etc.), have described a **fusiform pigmentation** of the posterior surface of the cornea, which some regard as congenital. Vogt considered it to be acquired and gave it the following characteristics, in addition to its fusiform shape :—

(*a*) Bilateral occurrence (19 out of 21 cases) ;
(*b*) Complete independence from persistent pupillary membrane ;
(*c*) Constant association with myopia ;
(*d*) Axial distribution of the pigment which reaches neither the inferior nor the superior limbus ;
(*e*) Appearance of the pigmentation in old people only.

A still rarer condition is also described by Vogt, namely a

mosaic pigmentation on the posterior surface of the cornea. The patient was sixty-six years old. In form the pigmentation was elongated in the vertical direction and symmetrical in the two eyes. The elements which composed it, hexagonal in form, probably corresponded to the cells of the endothelium.

Deposits of crystals of various kinds have been described in the cornea. Chevallereau (1891 and 1901), Uhthoff (1918) had already observed deposits of uric acid or of urates.

In a case of Koeppe's, there were seen round a focus in the cornea, which was probably tuberculous, little rhomboidal crystals, with a greenish lustre resembling snow, which this author supposes to be cholesterin.

In a case of Vogt's, needle-shaped crystals were grouped round a granuloma of the cornea. It could be seen with a high magnification that the needles were very fine and lustrous, and that in places they had a parallel arrangement.

The changes in a case of H. Coppez occupied an annular zone about 1 mm. from the limbus and left the axial parts of the cornea free. The ring was formed by a deposit of tiny crystals. There were also arborisations in the apparently healthy parts.

A patient of Urbanek's, aged twenty-five, showed a central leucoma in each cornea, which had been noticed ten years previously and which had undergone no change. The opacity was particularly dense at the centre. It involved the superficial layers of the parenchyma, and was composed of white crystals which seemed to be neither uric acid nor cholesterin. The nerves of the cornea were intact.

A patient of Lüssi's, sixty-five years old, had a little ectasia in the middle of the cornea, outlined by an opacity containing a brown line and whitish needle-shaped crystals.

We will review briefly the principal diseases of the cornea, always showing that no membrane presents such *individuality* as the cornea and that, if the slit-lamp is invoked to determine the precise characteristics of the classified classical entities, by

enriching our knowledge in an unsuspected manner, it will inevitably lead to an entirely new handling of it.

Keratoconus.—In addition to microscopic changes, keratoconus shows the following characteristics :—

(*a*) Thinning of the apex.
(*b*) Opacities at the apex.
(*c*) Striæ at the apex.
(*d*) Ruptures of Descemet's membrane.
(*e*) Fleischer's ring.
(*f*) Accentuation of the nerves.

The *opacities* are variable in form ; at first discrete, becoming more or less confluent, they may spread over and completely dull the summit of the cone. Their whitish colour is that of corneal nebulæ. Those which we have observed showed neither yellowish spots nor lines of Stähli.

The *striæ* should be carefully distinguished from opacities. The former are always very fine, more or less parallel, connected by anastomoses, which leave them at a very acute angle. Their direction is more or less vertical or slightly oblique. They look like cracks or fine sagittal clefts in the parenchyma. When there are opacities, the striæ seem to cross them or rather to be situated more deeply.

Thinning of the cornea at the summit is a change which the slit-lamp brings out in a most striking manner. The cornea is sometimes reduced by two-thirds. Often one sees, not far from its centre, in the posterior zone of specular reflection, a regular carpet of endothelial cells which are in no way affected. They are more easily seen here than in the normal cornea, on account of the excessive curvature.

The ruptures of Descemet's membrane are not constant, but if they occur, they are very striking and cannot escape the observer. They are seen in two ways, either in the zone of specular reflection or by transillumination. In the first method the edges of the rupture appear bright because the membrane is rolled back a little on itself. By transmitted light, the edges of the rupture appear dark. The rupture is sinuous and looks like a leech.

The endothelial cells are, of course, absent in the region of the rupture (zone of specular reflection).

Discovered by Fleischer (1906) and attributed by him to a deposit of hæmosiderin, Fleischer's **ring** is found in the epithelium. It may also be present in the form of an arc of a circle of varying size, or the line may even be broken. While Fleischer and Kraupa find this ring in all cases of keratoconus, we find with other authors that it is often absent, at least early in the case, while the opacities and striæ are already clearly marked. In histological examination Fleischer has noted that the ring gives a blue reaction with potassium ferrocyanide. The coloration seems to involve only the intercellular cement substance and not the cells themselves.

Finally, in keratoconus, *the nerves are more opaque*, if not thickened, and can be followed right to the centre of the cornea, unlike the normal. The hyperæsthesia of the apex is probably related to these changes. Polygonal thickenings of the nerve endings have also been noted (Strebel, Steiger).

Band-shaped keratitis usually begins near the limbus with the formation of a slight turbidity at the level of Bowman's membrane. In this haze are distinguished *dark, almost perfectly round holes*, which seem to us to be very characteristic of this affection. More rarely the disease begins at the centre of the cornea.

In degenerated corneæ, opacities are sometimes seen to form at a little distance from the limbus. They are possibly caused by calcareous deposits. But these opacities do not show the round holes of band keratitis, and have a tendency to spread along the limbus and not towards the centre of the cornea in such a way that one might call this affection in its typical form, which seems rare, it is true, **annular degeneration** (not to be confounded with marginal ectatic degeneration of the cornea).

It is certain that with the slit-lamp we diagnose band keratitis not merely weeks but months and years sooner than with ordinary means. Also, it is not unusual to make this diagnosis in an eye which is still enjoying fairly good vision. It is worthy of note that in early cases of both annular degeneration and band keratitis, the changes are always found in the region of

the interpalbebral fissure, a region which offers an obvious point of least resistance.

In a case of **sclerosing keratitis** in a woman of thirty years, in spite of the development of opacities, we have found it impossible to detect inflammatory signs.

In **epithelial dystrophy** such as Fuchs has described, with these characteristics : disc-shaped opacity, anæsthesia, vesicular degeneration of the epithelium, the microscope has brought out two new facts : *folding of Descemet's membrane and brownish coloration of the endothelium with loss of the cell outlines.* Of these two changes the folding seems to be the earlier.

In a personal observation, the patient came for examination as soon as he noticed impairment of vision in his good eye, the other being leucomatous. There was seen a central opacity of the cornea situated in the epithelium, which showed some vesicles and a depression, due, undoubtedly, to the bursting of one of these. Sensation was almost abolished ; the tension measured by the Schiötz never exceeded 30 mm. From the beginning, folds in Descemet's membrane were seen and also dark lines in the deep parts of the cornea. The endothelium was quite amorphous and faintly yellowish. In spite of all treatment, the condition became worse and led to blindness in a few months, without ever having hypertension or contraction of the visual field. In the meantime, moreover, the patient had undergone an operation for glaucoma.

This curious and apparently superficial condition, which one would localise at first entirely in the epithelium, is probably caused by serious trophic disturbances starting in the endothelium.

We will not dwell at length upon **bullous keratitis** such as follows prolonged hypertension and the diagnosis of which is obvious. However, as many authors frequently describe bullæ, we will point out that such a change, to merit this name, should possess definite characters : the presence of *two reflexes*, one from the convexity and one from the concavity, a *projected shadow* behind it and finally, if it is superficial, the narrow beam should confirm the protuberance that it forms in front.

In degenerated corneæ there are frequently seen rounded pits which on superficial examination may be taken for bullæ.

We do not understand the external bullous keratitis described by certain authors, and still less the internal form.

It is certain that authors have described under the name of **lattice keratitis** conditions which are different and cannot be grouped together. A number of these cases always appear to be caused by a chronic inflammation of the corneal nerves, which would form one element of the lattice, while a second would be furnished by the folds or ruptures of Bowman's membrane, and a third by the nodular swellings of the nerve endings.

Pillat would attribute the **nodular keratitis** of Grœnouw to thickening of the nerve endings and would thus group it with the lattice forms. The subject studied by this author was twenty years of age, and belonged to a family notoriously affected since the great grandfather. An elder sister showed the same clinical condition.

In a patient of eighteen, who had suffered from obstinate keratitis two years previously, Kraupa reported in addition to corneal hyperæsthesia, a greyish stippling situated especially in the superficial layer of the stroma and in relation with nerves of hyaline appearance, and thickened in places.

In an observation by Kleefeld, the nerves were clearly seen to become suddenly thicker at some distance from the limbus. There were also more or less diffuse opacities. Two subjects were brother and sister, aged fifty-six and fifty-three years. The affection had begun several years previously. A third subject was thirty-six years old. His mother was also affected.

In a case of Zaun's, the patient, aged thirty, had had eye trouble from birth. A sister was the same and a brother also saw badly. The patient counted fingers at 3 metres. The cornea was slightly hazy, especially in the central parts. The opacity contained little clear bullæ slightly raised above the surface. There were also multiple small opacities. By trans-illumination there were seen a number of dark sinuous lines, which, illuminated directly, appeared light. All these changes

occupied the superficial layers of the cornea and fluorescin stained a multitude of points. The author does not identify the sinuous lines with nerves, because they disappear towards the periphery and are especially well marked towards the centre of the cornea.

Similarly, we hear of affections due to diverse causes under the name **disciform keratitis.** Its features have been described authoritatively by Fuchs: a subacute or chronic affection, following a simple injury or a herpes, a discoid opacity in the middle of the cornea, having often a concentric structure, with absence of suppuration. If it is true that it sometimes follows herpes febrilis, a point on which Erlanger and P. Knapp insist, it is not admissible that it is the inevitable sequel to this condition.

On the other hand, what Duverger describes as **traumatic interstitial keratitis** is obviously allied to the condition described by Fuchs.

At all events, the slit-lamp throws into relief an important feature in the cases of disciform keratitis: thickening of the centre of the cornea shown by an *annular reflex* (Vogt). Frequently, also, folds in Descemet's membrane may be seen, and more rarely changes in the nerves and precipitates on the posterior surface, the last limited exactly to the infiltrated area of the cornea, as Vogt and we ourselves have often seen. This last phenomenon shows the weakness of the hydrodynamic theory of the formation of precipitates. Chemiotactic stimuli seem also to play a part.

In **keratitis punctata superficialis** it is advisable to use at first a wide beam to explore the whole surface of the cornea. We find little whitish patches of varying sizes, the larger ones apparently formed by fusion of smaller ones, not always staining with fluorescin. Parenchyma and endothelium remain intact.

Dendritic keratitis (herpes febrilis) is particularly well studied after the instillation of fluorescin. A low magnification suffices. (F 55, oc. *a* 2.) It is essential to make the examination immediately after the instillation because diffusion of the

fluorescin quickly effaces the dendritic figure. Occasionally the vesicles themselves are seen, more often superficial erosions. On examining an epithelial abrasion, the following curious phenomenon will be seen. The next day and for one or two days following, the dendritic figure still stains clearly, although apparently re-covered by a new and absolutely intact epithelium. Later no staining occurs. Left to itself, herpes extends superficially or goes on to the formation of a disciform keratitis. The presence of thickening of the cornea, and of folds in Descemet's membrane renders the prognosis more grave.

Herpes zoster (**zona**) determines the formation of *characteristic opacities:* rounded spots, fusing in geographical areas, and composed of little white dots.

A **recurrent abrasion** shows under the microscope fine confluent droplets forming zigzag lines staining with fluorescin.

Ocasionally a *flattened bulla* is seen resulting from a localised separation of epithelium. Vogt has observed such a separation with a diameter of 1·5 mm. in parenchymatous keratitis. It disappeared without bursting. Such formations are seen also in the epithelial dystrophy of Fuchs.

In **irido-cyclitis** Vogt has observed prominences of epithelium of a mean diameter of 0·2 mm. persisting for several weeks and leaving behind superficial grey spots of corresponding size. Examined in the zone of specular reflection, these prominences give a feeble reflex. In the anterior band they show as rather clear greyish spots. In transillumination they have the appearance of a heap of very fine droplets. Similar formations may be seen in *keratitis punctata superficialis;* but those of irido-cyclitis provoke fewer objective phenomena, are more stable, and seem to be more localised in the interpalbebral area.

In **deep pustular keratitis,** which, as we know, is usually, if not always, of a specific nature, the slit-lamp reveals the deep seat of the lesions and the thickening of the cornea. In a case of Schneider's there were two yellowish foci, deep, ill-defined, with radiating opacities of fine precipitates on Descemet's membrane and a hypopyon of 3 mm.

Parenchymatous keratitis may be diagnosed very early with

the aid of the slit-lamp. The epithelium shows a *marked bedewing; cloudy opacities* appear in the parenchyma; *the cornea is thickened.* Sometimes the opacities of the parenchyma extend in concentric layers to the surfaces of the cornea; the narrow beam shows this particularly well. The opacities which result from infiltrations may also maintain this appearance. *Folds of Descemet's membrane* and *precipitates* of various sizes also appear very early sometimes.

The microscopic appearances may precede the circumcorneal injection by several weeks, as is shown by a case of Vogt's. The right eye had already had an attack of interstitial keratitis. The first change in the left eye was an opacification of the deep layers of the cornea extending in crescentic shape in the lowest part of the cornea, then advancing towards the upper part while becoming thicker sagittally. Some days later discrete precipitates appeared in this region, as well as little nebulæ in the corneal stroma. The posterior zone of specular reflection showed an endothelium of indistinct cells, with projections of 20 to 40 microns into the anterior chamber, partially confluent and appearing dark. The cornea was very much thickened. At this stage there were still no newly-formed vessels.

Further, the opacities of parenchymatous keratitis leave behind two characteristic changes: thinning of the cornea, and vessels in the deepest layers. The thinning is sometimes so excessive as to reduce the cornea to half its original thickness. It may be localised but oftener involves the whole membrane. Ectasia rarely occurs. The vessels are particularly well seen by transillumination. They are very numerous, more or less narrow and more sinuous than the classical description would suggest. If we focus the posterior zone of specular reflection of the cornea with its endothelium, we see that it is cut by one or more dark lines, thinner, blacker and clearer than the folds in Descemet's membrane. These lines are no other than the remains of deep vessels. It may be proved by the use of the microscope that interstitial keratitis leaves indelible traces in the form of obliterated vessels.

Under the name of **posterior herpes of the cornea,** Schnyder describes a curious condition, of which he has seen three cases in several years. It occurs in people suffering from *recurrent attacks of herpes labialis*, which seem to become gradually less severe. The patient complains of pain in the eye, although there is no appreciable injection. By focal light, there is seen on the posterior surface of the cornea, a *more or less rounded superficial opacity*, like a thin veil containing a *few very stable bullæ having a clear reflex* and measuring from 0·05 to 0·1 mm. in diameter. If these changes are focussed in the posterior zone of specular reflection, it is found that the bright yellow pattern of the endothelial cells is marked by dark holes in the situation of the bullæ. The outlines of the cells cannot be seen in the area of the bullæ.

The opacity at the surface surrounding the bullæ, their visibility in focal light, and the coincidences of herpes labialis are sufficient to differentiate these changes from the Hassal-Henle bodies, which can be seen only in the zone of specular reflection.

Finally in **leprosy,** there may be seen, according to Morax, a slight clouding of the cornea and small nodules in the anterior layers of the cornea (*cf.* iris). In one case of this author, these alterations preceded the involvement of the iris. Meller has also drawn attention to the whiteness of these nodules, consisting of a mass of bacilli and round cells (keratitis punctata superficialis of leprosy).

CHAPTER VI

THE ANTERIOR CHAMBER

SPECIAL TECHNIQUE

Examination of the anterior chamber with the exception of the peripheral parts, presents no special difficulty.

The *incidence* of the beam will be variable. As delicate structures reflecting little light, such as exudative pseudo-membranes or minute particles, usually have to be examined, it is advantageous to dispose the beam in such a way as to avoid completely the regular reflection of light by the cornea.

Blood corpuscles, pigment granules, illuminated by a narrow beam, are seen in the same way as atmospheric dust, when shown by the sun's rays in a dark room. Here we apply one of the principles of the ultra-microscope by making use of a narrow beam, the slit being reduced by at least half.

Indirect and transmitted light will find little application. On the other hand, there is nothing which can furnish zones of specular reflection in the anterior chamber.

THE NORMAL ANTERIOR CHAMBER

In the normal state, the aqueous humour is almost absolutely transparent and the anterior chamber " optically empty." That is to say, it appears practically black. However, as Vogt has shown, on sending the upper part of the beam into the pupil and comparing its path with the unilluminated part, it is just possible to perceive that the unilluminated part of the anterior chamber appears even slightly darker than the path of the beam.

The presence of corpuscles, pigment granules, etc., in the aqueous humour, facilitates the study of the circulation in the anterior-chamber.

The origin of the line of Ehrlich-Türk has been exactly

established by the observations of Erggelet, Berg, Plocher, who show the existence of *convection currents* in the interior of the anterior chamber.

The whole aqueous humour is in perpetual movement in a direction which may be defined thus : *the aqueous rises in front of the iris and descends behind the cornea.* It is certain that the movement is of purely physical origin. Indeed, there exists an important difference of temperature between the posterior wall of the chamber (iris and lens) and the anterior wall (cornea), a difference which Silex estimates at 7° C. Michel points out that if the rectal temperature of the rabbit is 38·5° to 38·9°, the middle of the anterior chamber is at 31·9° and the lens at 36·1°. This difference is sufficient to cause convection currents.

Berg established, by the two following proofs, the fact that the circulation of the aqueous is of a purely thermic nature :

(*a*) If the head is inclined sideways, the central ascending current maintains its vertical direction ;

(*b*) If the cornea is bathed in a liquid which is contained in a glass chamber, and whose temperature can be raised, it is noticed that the current slows or even stops completely if the difference of temperature between the cornea and iris disappears.

Finally, Plocher has noted that the aqueous current cannot be seen in a patient who has been reclining up to the moment of examination, but needs about ten minutes to become established.

It is in front of the middle of the pupil that the current, in ascending, presents its maximum speed, which authors estimate at 1 mm. in three or four seconds.

The following fact may also be observed : in the examination with the slit-lamp, if the same place be illuminated for long enough, it is seen that the particles rise more rapidly if they are already ascending, or even stop and begin to rise if they are descending. This phenomenon is due to the effect of the heat from the beam.

Weekers, on injecting a drop of Chinese ink into the vitreous of a rabbit, saw particles of carbon appear in the anterior chamber at the end of about an hour, and later disappear. Here he made use of a physiological circulation.

In the normal state, isolated cells, probably white corpuscles, are frequently seen in the anterior chamber. Erggelet, with the Nernst lamp, observed them in only 2 per cent. of the cases

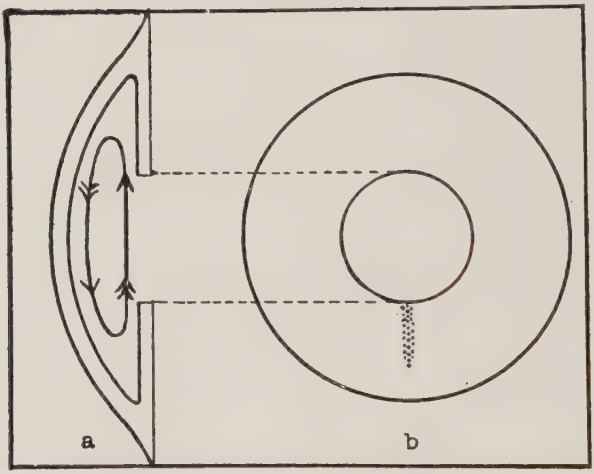

FIG. 26.—Diagram showing the thermic circulation of the aqueous humour. On the left (*a*), sagittal section of the anterior chamber; on the right (*b*), frontal view. In *b* is seen the line formed by microscopic deposits on the posterior surface of the cornea.

examined. Careful examination with the Nitra lamp gives a considerably higher proportion.

A phenomenon depending upon the circulation in the anterior chamber is the **deposit of cellular elements** on the posterior surface of the cornea, which Lüssi finds in 50 per cent. of children from seven to sixteen years. These cellular elements number ten or more and are grouped along a vertical line (Türk's line), in the middle of the posterior surface of the cornea, the upper part of the line being at the level of the lower border of the pupil. Each cell is 10 microns in diameter. These corpuscles are also seen by transillumination. Their border is lighter

than their centre. They are not stable but disappear in the horizontal position. They have no relation to pigmentation of the iris (*cf.* Fig. 26).

Mlle. Guggenheim also finds cellular deposits in half the children examined from seven to sixteen years, and in about a third of the patients with foreign bodies. The deposits usually number ten to thirty, and may be as many as fifty.

This line of cellular deposits should be regarded as normal in children. In irritation of the globe, when they are dust-like in character, they are deposited on the back of the cornea over the same area.

The " physiological " cells are in all probability white corpuscles. Moreover, Vogt has observed that they show amœboid movements on the cornea, and may either remain stationary, or move about in all directions. They show no tendency to agglomeration, which distinguishes them from pathological precipitates. Each cell measuring on an average 10 microns, takes one or two seconds to move as far.

CONGENITAL ANOMALIES

Any *abnormality in the depth* of the anterior chamber may be measured by means of Ulbrich's drum (*vide supra*). This method gives the optical depth of the chamber. The surface of the cornea is first focussed exactly and the scale set at zero. Then the surface of the iris is focussed near the pupillary margin. The movement of the microscope indicates the depth of the anterior chamber.

The depth of the chamber varies with the age, refraction and accommodation of the subject. Several authors have made measurements with the aid of various methods. Some figures will be given below.

As is known, in buphthalmos the chamber is deepened, while in microcornea it is obliterated. Exact measurements have not yet been made on the living in a systematic manner.

With the slit-lamp, the observed eye looking straight forwards and the beam entering it at a known angle, the depth of the anterior chamber may be judged approximately.

Remains of the pupillary membrane are extremely common. Frequently they are so small that some care is needed for their detection.

With the lamp on the observer's left, the light is focussed on the anterior lens capsule, the whole of which is swept from left to right. The very fine remains are then seen shining white, to the left and in front of the illuminated lens capsule, forming sometimes a regular anastomosing network. These remains are seen to the left of the anterior band of the lens, because they show up there on a dark background. In the illuminated area of the lens capsule they disappear almost completely.

If they are very fine, it is rather a delicate matter to trace them on the iris, for they are always dragged upon by the movements of the iris. It will be observed that they are *always connected to the collarette* (and not to the pigment border), that they frequently cross the pupil and that they are often crossed underneath by other filaments.

The fine remains are generally unpigmented, whereas the thicker strands are usually brown ; lastly, nodules of different sizes, usually pigmented, are often seen. Perfect elasticity is a property of all these filaments.

Occasionally a persistent pupillary membrane is associated with an anterior capsular cataract. In these cases the cornea usually shows an opacity, evidence of an intra-uterine perforation. It occurs then always as coarse threads of unequal thickness, which form a network with its thickest strands converging towards the capsular cataract, whose seat is exactly central. Here also the filaments exhibit astonishing elasticity.

SENILE MODIFICATIONS

As is known, the anterior chamber becomes gradually *shallower with age*, as the lens increases in size.

Different observers have measured its depth by various methods, with results which are in general agreement.

Saunte, using an ophthalmophakometer, slightly modified from that of Tscherning, has taken measurements from fifty individuals and has obtained the following figures :—

From 10 to 20 years . . .	3·71 mm.
,, 20 ,, 30 ,, . . .	3·51 ,,
,, 30 ,, 40 ,, . . .	3·43 ,,
,, 58 ,, 67 ,, . . .	3·22 ,,

The diminution in depth amounts, therefore, to rather more than $\frac{1}{2}$ mm.

Lindstedt, using an original method, has examined the eyes of 100 emmetropes and obtained figures comparable to those above :—

From 0 to 15 years . . .	3·68 mm.
,, 15 ,, 30 ,, . . .	3·70 ,,
,, 30 ,, 50 ,, . . .	3·56 ,,
,, 50 ,, 80 ,, . . .	3·21 ,,

The slight increase in depth between fifteen and thirty years is not confirmed by Raeder, who also employed an original method :—

At 15 years	3·69 mm.
,, 25 ,, ...	3·57 ,,
,, 35 ,, ...	3·42 ,,
,, 45 ,, ...	3·37 ,,
,, 55 ,, ...	3·15 ,,
,, 65 ,, ...	3·04 ,,

It will be remembered that these figures indicate the distance between the surface of the lens and that of the cornea.

Occasionally *floating crystals*, probably of cholesterin, have been observed in the anterior chamber. This phenomenon is not, however, a normal senile change.

In a case of Handmann the cholesterin crystals were numerous enough to form a deposit simulating hypopyon.

TRAUMATIC LESIONS

After a rather violent **contusion of the globe,** fine dust is generally seen in the anterior chamber. This dust, composed of the cellular elements of the blood or their derivatives, and of

liberated pigment granules, allows the circulation of the aqueous humour to be studied. They are rapidly reabsorbed.

Similarly, when a **foreign body** is embedded in the cornea, elements are seen to appear in the chamber, which become distributed along the line of Ehrlich-Türk.

In **subluxation of the lens** a prolapse of the vitreous is often seen appearing at the pupillary border, bulging the iris a little and detaching it from the lens capsule. The surface of the hernia gives a reflex which enables us to judge of its form. In it are seen a fine irregular retiform structure and brown pigment granules. It is sometimes not easy to distinguish a prolapse of vitreous from a network of fibrin. The first is recognised by the pigment granules which are, we believe, invariably present, and by the fact that it is always in relation with the pupillary margin.

Stajduhar reports a curious observation of a **free cyst** floating in the anterior chamber. It was a case of a soldier of twenty-four, who had a contusion of the eye. The lens showed cortical opacities and the iris remains of the pupillary membrane. The cyst was brown, kidney-shaped, 1·5 by 2 mm. in size, with transparent walls, and quite free.

PATHOLOGICAL CHANGES

Changes in the anterior chamber, which is devoid of vessels, consist entirely of opacities which can be divided into several groups theoretically.

(*a*) A uniform *cloudiness*, the elements of which cannot be distinguished, even with the highest magnifications. It is revealed by the beam whose passage produces a faint whitish flare.

(*b*) *Turbidity* produced by visible corpuscles of different sizes, ranging from very fine dust, clearly marking the line of Ehrlich-Türk, to gross opacities, visible to the naked eye.

All these elements are liable to be deposited on the posterior surface of the cornea. In the formation of precipitates several factors are concerned: the normal current of the aqueous

humour, the weight of the corpuscles, centrifugal forces developed by the movements of the globe (Erggelet), physico-chemical properties, such as surface tension, etc. (Stähli), chemio-taxis by the living cells.

(*c*) *Reticular opacity* produced especially, if not only, by fibrin.

(*d*) Finally, *large agglomerations*, which sink by their own weight to the bottom of the anterior chamber, *hyphæma*, *hypopyon*.

A combination of these different kinds of opacities may be found.

Any uveal affection may cause opacity in the aqueous humour. The same is true of all forms of keratitis.

When, as a result of pathological states, the anterior chamber appears to be completely effaced, one may often, with the narrow beam, find places other than in the pupillary area, where the cornea is not in contact with the deep parts, and where what may be called **relics of the anterior chamber** persist. Such relics are more frequent outside the collarette than inside it (Vogt). The posterior surface of the cornea may model itself upon the iris when they have remained long in contact, and localised thickenings may appear on the cornea, which will be revealed by the narrow beam.

Reticular formations may also be observed after parenchymatous keratitis. These cobweb-like opacities are stable, unlike fibrinous threads. In a case of Vogt's, the patient had suffered for two years from parenchymatous keratitis. Only a detailed examination revealed the fact that the network was not adherent to the posterior surface of the cornea, but suspended parallel to it and at a little distance from it. Pigment was deposited in places on the network, as also on the posterior surface of the cornea.

In another observation by the same author, the network was still more heavily pigmented, and the patient (sixty years old) had suffered for two months from a subacute kerato-iritis of unknown origin.

Sometimes there may occur actual **pseudo-membranes** of

exudative origin which can be correctly localised by the slit-lamp. In iritis, such reticular formations or pseudo-membranes are at first connected with the surface of the iris, from which they may ultimately become detached. On the other hand, in deep infiltrations of the cornea, the formation starts from the posterior surface of the cornea, from which it may become detached, forming a pedicle, as in a case of Vogt's, where a disciform keratitis had formed in a young man of nineteen. At the fourth week there appeared a cloudy whitish mass, full of pigment granules, suspended by a pedicle from the posterior surface of the cornea. Finally this mass produced transparent spherules, the biggest of which measured 0·33 to 0·37 mm. in diameter.

CHAPTER VII

THE IRIS

SPECIAL TECHNIQUE

Oblique and indirect illumination and transillumination will be used. The tissues of the iris reflect too little and absorb too much light to give rise to regular reflection producing zones of specular reflection.

Oblique illumination (direct) serves for the examination of the superficial layers of the iris and of the pigment border. It will be used also to determine whether an iris is free from synechiæ. For this purpose one moves the beam, followed by the microscope, using a low magnification, round the whole pupil, and one is thus able to discover any synechia, however small. The extraordinary mobility of the iris under the beam of light is, moreover, a striking spectacle to the beginner. With this light well focussed it will be possible very frequently to detect *local reactions of the iris to light* or simple tremors of the sphincter which escape the naked eye completely.

Indirect illumination serves especially to throw the sphincter into relief and to show tiny hæmorrhages not otherwise visible, as well as neoplasms and cysts.

The *incidence* of the beam will vary according to the object to be examined. An incidence of 30° to 45° is indicated for the examination of the superficial layers. The angle will be a little wider for examination by the indirect method and still wider for *transillumination*. In transillumination it is the lens which plays the part of a *reflecting screen*. The light is, therefore, directed *into the pupil* (diapupillary or transpupillary illumination). A cataractous lens will naturally reflect more light than a transparent one, but even with a clear lens, suffi-

cient light is reflected. In aphakia, transillumination is less practicable.

The iris may also be examined by transillumination by illuminating the globe *through the sclera*. For this purpose the arc lamp is needed. With the Nitra lamp the slit must be widened to its fullest extent.

In diapupillary transillumination, if the nasal part of the iris is to be explored, the lamp will be placed on the temporal side of the patient, and *vice versa*.

THE NORMAL IRIS

The structure of the iris varies so considerably in different individuals, that one can only recommend the beginner to examine a large number of irides in order to be able to judge of their normality.

The amount of stroma *pigment* is very variable and is largely responsible for the multiplicity of structural appearances. The luminous beam penetrates much more deeply into the blue iris than into the brown. As for grey irides, one can often verify the assertion of the old anatomists (Manz, etc.), that their tissue is more compact than that of the blue.

The blue iris presents the appearance of a very delicate, almost airy tissue. The fibres and trabeculæ look like transparent wool. The deeply pigmented iris has, on the contrary, a smoother surface, a more compact tissue, suggesting the appearance of tinder.

Even in an iris which appears quite blue to the naked eye, it is almost always possible to make out under the microscope groups of chromatophores producing yellow spots in the superficial layers of the stroma. These cells are never seen otherwise than in groups. In certain domestic animals, with only a fairly high magnification, the spidery character of the pigment cells can be seen.

In certain individuals the pigment is disposed in brown patches which stand out in relief on a light background (*piebald iris* of the English). These spots are scattered over the whole

surface of the iris. It is not unusual to find darker spots on uniformly pigmented irides. If these nævi are situated near the sphincter they are probably composed of the *cells of Koganei (Klumpenzellen)*. But we have no means of verifying this fact in the living eye.

With microscopy in the living eye, one can recognise that the

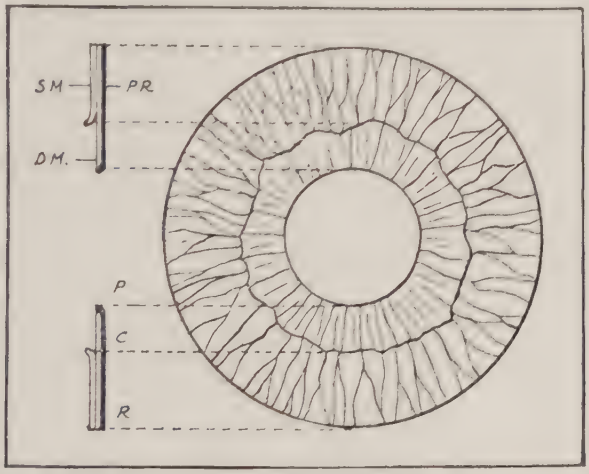

Fig. 27.—Diagram showing the structure of the iris. The retinal layer appears at the edge of the pupil, where it forms the pigment border. The mesodermic layer is separable into a deep layer running from the root of the iris to the pupil and a superficial, the axial limit of which forms the collarette. *SM.* Superficial mesodermic layer. *DM.* Deep mesodermic layer. *PR.* Posterior retinal layer. The crypts of the iris, situated in the ciliary portion, may be considered as openings distributed in the superficial mesodermic layer (anterior). *P.* Pigment border. *C.* Collarette. *R.* Root of iris.

iris is composed of a deep pigmented (retinal) layer, which is seen more or less at the bottom of the crypts and at the pupillary border, and of *two* mesodermic layers, of which the *deeper* extends from the ciliary to the pupillary margin of the iris, while the *superficial* extends only from the ciliary border to the *collarette*. The collarette, the more or less continuous and marked axial boundary of the superficial layer, is detached from the deep layer to a varying extent, and thus forms *the angle of Fuchs* (*vide* Fig. 27).

The *vessels* of the iris are partially visible but only if it is not pigmented. Radial trunks can then be seen, which reach as far as the collarette and changing direction, follow one of its trabeculæ, quickly disappearing. There is not a true vascular circle at the collarette; hence we avoid the expression "circulus iridis minor." The normal vessels are always surrounded by a thin layer of connective tissue and are never placed directly on the iris, a point upon which Koeppe insists.

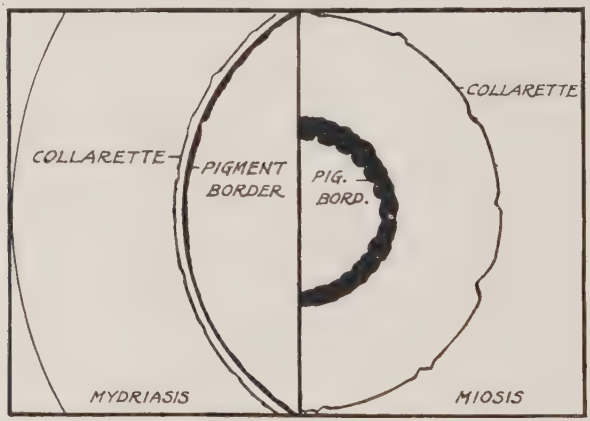

FIG. 28.—Diagram showing the relations of the pigment border and collarette and the variations in thickness of the former according to the width of the pupil. To the left, pupil dilated; to the right, pupil contracted.

As for the *nerves*, they remain completely invisible, and the same is true of the dilator muscle.

On the surface of blue irides is seen, especially with indirect illumination, an appearance as of fine muslin, possibly produced by the endothelial cells.

The **collarette** is more or less marked, according to the eyes, by a series of trabeculæ, forming a broken line circular in general direction. Filaments of a persistent pupillary membrane, sometimes very fine, frequently connect these and may cross the pupil. *The wider the pupil, the nearer is the collarette to the pigment border*, so that, with a sufficiently dilated pupil, the

two coincide. These features are easily studied in eyes which are not deeply pigmented. This relation of the collarette explains how filaments of a persistent pupillary membrane, when the pupil is dilated, appear to be attached to its margin, while actually they are still attached to the collarette.

The **sphincter** is visible only if the tissue of the iris is moderately pigmented. It can sometimes be seen in an iris which is sufficiently pigmented to appear yellow. It is best seen

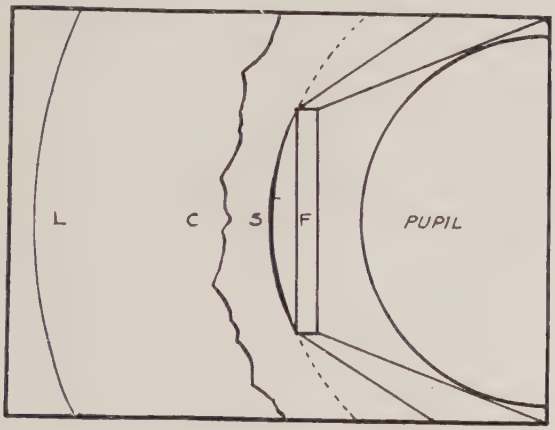

Fig. 29.—Diagram showing the method of making the sphincter of the iris appear. The light comes from the right. *F.* Focal part of the luminous beam. *S.* External border of the sphincter. *C.* Collarette. *L.* Sclero-corneal limbus.

by indirect illumination ; it is seen by transillumination only when the iris tissue is considerably atrophied. To examine the nasal portion of the sphincter, one focusses the beam on the edge of the pupil, then moves it slowly towards the periphery. The crescentic outer border of the muscle is seen to appear standing out clearly from the surrounding tissues (*cf.* Fig. 29). The outer edge of the sphincter is always better marked than the inner, which is near to the pupil. If the pupil is small or only semi-dilated, the outer edge of the sphincter is within the collarette and separated from it by an appreciable space.

CONGENITAL ANOMALIES

Levinsohn and Lindberg have described **notches** in the *pupillary border* at which the pigment border may be intact or may be lacking. According to the second author, they have no seat of predilection and are derived from similar formations seen in the eyes of embryos. There may be several notches in the same eye.

While Gallemaerts and Kleefeld always find the pigment border interrupted at the site of a **congenital coloboma** of the iris, Koeppe observes that it is considerably thinned. In a personal observation, it was of normal appearance in the coloboma as elsewhere.

Aplasia of the superficial mesodermic layer of the iris manifests itself as a rarefaction of the superficial tissue in the lower part of the iris, allowing the retinal pigment layer of the iris to show through and to give a different colour to this part (Fuchs, Arnold).

At other times there is a veritable **pit** (Streiff), which is exaggerated especially during accommodation, and which is always situated in the lower part of the iris. In 188 school-children of six to fifteen years, Streiff finds this anomaly well marked in forty-six and less marked in twenty-five. In three-quarters of the cases, the two eyes presented the same appearance.

In a case of congenital aplasia of the anterior layer in mother and daughter, Urbanek was able to study changes in form of the posterior layer depending upon changes in size of the pupil : there was a concavity when the pupil was large, a convexity when it was small.

In **melanosis** of the iris (hyperpigmentation), there is such a rich pigmentation that it forms a continuous opaque layer. The surface of the iris is usually smooth, or even shows the *verrucose condition* described by Coats, Fleischer, etc.

In **partial congenital heterochromia** a perfectly brown sector may be seen in a grey or blue iris. This anomaly must not be confused with ectropion of the uvea. The very pigmented part

usually presents the form of a sector, more rarely that of a segment. It may also be more or less linear or semi-circular. The presence of spots is so frequent as to be regarded as normal.

In **congenital heterochromia** of the iris, the dark part may be simply very pigmented or *hyperpigmented*. In the latter case the sclera also shows melanotic patches and the surface of the iris is often verrucose.

We have observed a certain number of cases of **simple pigmentation** in which the most minute examination revealed no pathological signs.

Heterochromia with precipitates and cataract is pathological, although the congenital factor seems to play a part in it. We shall refer to it again.

Earlier authors have already described a congenital malformation of the pigment border of the iris visible to the naked eye. It takes the form of a thick roll with localised nodules. It is ill defined peripherally, and not demarcated from the stroma. There is no collarette, so that it would appear that a **circular congenital synechia** exists **between the collarette and the pigment border.** The synechia may be only partial and involve only a small portion of the pupillary circumference. Sometimes, also, the collarette merely sends out fibrous tracts, which are inserted at the pigment border in the form of *claws* (Stromakrallen of Vogt). These processes need not be in connection with the collarette.

In **congenital reduplication of the pigment border** one sees that over a certain distance, much more rarely over the whole circumference, an interrupted circular furrow divides it into a peripheral and a central part. This anomaly was hereditary in a case of Vogt's.

Congenital defect of the pigment border is rare. It should be apparent in miosis. In a personal observation, the pupil was slightly larger on the side where the pigment border was defective and the colour of the iris was also lighter. **Aplasia** of the pigment border in the lower part of the pupil is common.

Flocculus of the iris is a congenital hyperplasia of the normal villi in the upper part of the pupil. The brown masses, like

rounded and bulging fringes, seem to arise from the posterior surface of the iris rather than from the edge of the pigment border. According to Vogt, flocculus is transmitted in the human species as a sex-linked character, for which reason it is more common in men than in women. The same author distinguishes a lamellar form (*Eversio exfoliativa*) and a nodular form (*E. tuberosa*). The first may be regarded as being produced by excessive growth of the pigment border. The second owes its origin to a nipping off of the mass of pigment by fibrous processes of the mesoderm.

As regards **the ectropion of the uvea** of the authors, it is seen not only in apron form, but even more often as a more or less elongated crescent. This latter variety is naturally better seen in mydriasis than in miosis. The everted surface is smooth or finely and irregularly striated.

Persistent pupillary membranes (*vide supra*, p. 112), studied by Bruckner, are connected with the collarette. They are found more or less marked in about half the cases examined.

SENILE MODIFICATIONS

Senile modifications in the iris consist of atrophic processes and pigmentary disintegration.

Atrophy of the stroma involves especially the pupillary part, which, becoming thinned, allows the retinal layer to show through and to cause a change in colour of the iris, making it more grey or dull brown. A second result of this atrophy is to make the sphincter more easily visible in old people.

Sometimes there is seen a little *circumpupillary furrow* (*Sulcus circummarginalis*) of Vogt, concentric with the pigment border and completely surrounding the pupil. In other cases, atrophy of the mesodermic tissue causes the appearance, at the pupil margin, of a brownish circular zone in which are seen whitish filaments disposed in a radial manner, remnants of the atrophied layers. The atrophy can also be confined to a sector.

The processes of **depigmentation** of the iris have been studied in recent years by several authors, for some of whom (Axenfeld,

Mawas) they had all the more importance in so far as these writers had wished to associate them with senile cataract.

The slit-lamp shows us that *this disintegration of pigment is a constant senile phenomenon.* It can be seen by oblique illumination if it involves the pigment border, or by transillumination if it involves the posterior layer. Transillumination by contact lamps had already established the occurrence, in old age, of lacunæ in the retinal layer. Certain authors (Höhmann, etc.) consider that the scattering of pigment is caused by actual *mechanical wear and tear*, which would occur chiefly in the neighbourhood of the pigment border.

The Bâle statistics (Hinnen) show the frequency of senile changes. The figures indicate the percentage of persons *unaffected* :

Ages.	Subjects.	Atrophy of the Stroma.	Atrophy of the Pigment Border.	Atrophy of the Posterior Layer.
1 to 10 . .	57	100·0	100·0	100·0
10 ,, 20 . .	190	100·0	92·0	100·0
20 ,, 30 . .	52	98·1	76·9	98·0
30 ,, 40 . .	9	88·9	44·4	100·0
40 ,, 50 . .	21	57·1	9·5	90·5
50 ,, 60 . .	34	44·1	5·9	91·1
60 ,, 70 . .	41	12·2	—	58·5
70 ,, 80 . .	51	3·9	5·9	19·6
80 ,, 90 . .	7	—	—	14·3

Disintegration of the pigment border is easily seen by oblique illumination. One sees irregular lacunæ formed in several places at once. *The pigment granules swarm over the neighbouring parts of the stroma*, giving them a brown colour. With a sufficiently high magnification, it can be seen that they lie very superficially on the trabeculæ and in the crypts of the iris tissue (*cf.* Fig. 30).

Depigmentation of the pigment border may also occur in the form of small *cuneiform sectors* with their bases at the pupil, or

as *radial fissures* continued on the posterior surface of the iris, possibly as far as its root.

Where the pigment border is atrophied, the neighbouring stroma frequently undergoes senile regression, becoming thinned and frayed so that the pupillary border is quite irregular. These changes do not necessarily indicate an irido-cyclitis, although they occur in a more marked degree in this condition.

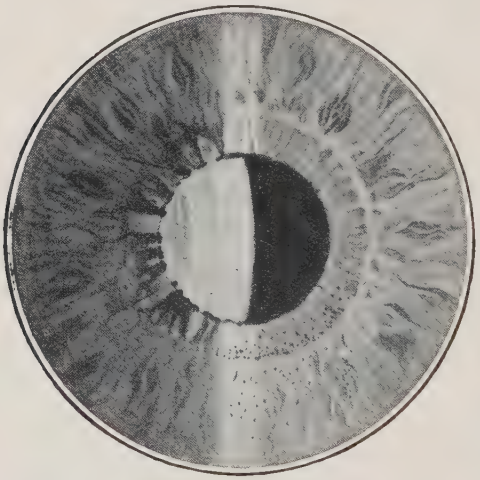

Fig. 30.—Senile pigmentary disintegration. There is seen, corresponding to the anterior band of the lens, the trace of the luminous band on the iris. The light comes from the right. The granules of pigment are well seen in focal light. On the left are seen, by transillumination, gaps, chiefly cuneiform in shape, produced by destruction of the retinal layer.

In advanced age the pigment border may be completely devoid of pigment. In its place one sees then a greyish pellucid border composed of the stroma itself.

The atrophic pigment border may present another aspect due, not so much to depigmentation as to the *apposition* of pigment on its surface, forming roughenings and irregular deposits. Accumulation of pigment in some places and depigmentation in others may give the border a jagged appearance.

Generally speaking, depigmentation of the pigment border is more frequent or more easily seen in blue or grey irides than in brown.

Depigmentation of the retinal layer in general begins with that of the pigment border. It may happen, however, that this is almost intact while transillumination (transpupillary illumination) reveals irregular lacunæ or thin translucent areas in the retinal pigment layer.

The *sphincter* participates in the senile changes. It appears that its tissues become opaque, a phenomenon which, along with the rarefaction of the iris stroma, renders the muscle more easily visible. More rarely, thinning of the sphincter may be observed. This may be considerable and may involve the whole circumference or only a part. In marked cases, it gives the impression that the sphincter has shrunk away from the peripheral part of its bed, which then becomes visible as a darker ring.

TRAUMATIC LESIONS

After injuries to the iris, **ruptures of the pupillary margin** are frequently seen. The rupture may involve the sphincter or only the superficial layers. One sees then irregular radial splits, the damaged fibrous processes separating more, the more superficial they are. After some weeks the appearance is less marked.

Any traumatism may also liberate pigment which is found either in the aqueous humour, on the iris, or in the vitreous. This, of course, occurs also after surgical interference. As is well known, this scattering of pigment is considerably greater in diabetes.

Ecchymoses of the iris, if they are small, can only be recognised by indirect illumination. In moving the beam across the iris, one sees the red spot suddenly appear and disappear again when the light impinges directly upon it. Very rarely one may see a tiny hæmorrhage appear spontaneously and disappear again in an old person.

In cases of perforation of the cornea by foreign bodies, the iris should be carefully examined. Sometimes a **hole** will be found right through it, visible also by transillumination. Sometimes, also, **foreign bodies** will be found either on or in the iris. It is not unusual after mine explosions to find on the iris numerous tiny bits of flint, which are sometimes comparatively well tolerated.

After an injury, part of the superficial layer of the mesoderm may be detached from the deep layer. **In this partial rupture**

of the superficial layer *the parts detached are remarkably rigid* and no longer follow the movements of the iris. In a case of my own, a few detached trabeculæ in the shape of a peak cap, approached so closely to the cornea and showed so little movement that at the first glance there appeared to be an anterior synechia. The slit-lamp, however, showed the absence of a synechia (*cf.* Fig. 31).

Bailliart has observed a "detachment of the superficial layer of the iris" after a violent traumatism which had caused retinal

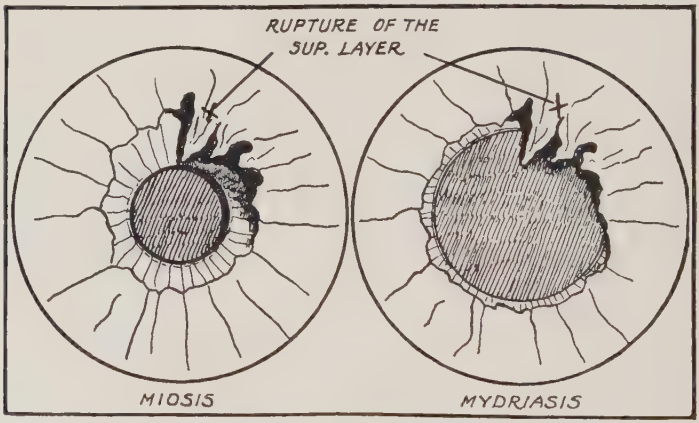

Fig. 31.—Traumatic partial rupture of the superficial mesodermic layer. Figure from nature, slightly schematic. The detached part of the superficial layer remains inert during movements of the pupil. On the left the pupil is contracted, on the right dilated.

hæmorrhages and detachment. The detached part was floating in front of the upper part of the pupil. As this was deformed, it was probably not a rupture of the superficial layer alone. Bailliart has attempted to make the mechanism of the detachment attributable to the pressure of the aqueous humour diffusing into the iris by the crypts.

Cases of almost complete detachment of the superficial layer of the mesoderm have been reported (Schmitt, Mlle. Drapkin). The cause is still obscure.

Post-traumatic heterochromia of the iris has been described by Vogt. In all his cases the eye had been injured several

years before the examination (twenty-two to thirty), during the subject's early life (nine to twenty-three years). The injured eye showed a pigmentation similar to the normal but *darker*. The superficial layer of the mesoderm was especially pigmented. There were often well-marked nævi of the usual appearance. The brown colour was produced by two factors, a diffuse brownish coloration of the stroma and chromatophores. There were distinct indications, however, that the iris tissue had undergone a certain amount of atrophy (obliteration of the collarette, which recedes from the pupil, etc.).

In an observation of my own, a young man had been injured at the age of eight by an "eureka" arrow. An iridectomy must have been made at about "7 o'clock" and the lens extracted. At twenty, the patient showed a uniformly greenish yellow iris on the left. The right iris was blue in its ciliary part and a little pigmented in its pupillary part. This case shows that post-traumatic heterochromia may be established in the space of about ten years, although in the cases cited above the period is at least twice as long.

In **siderosis** of the iris the well-known rust colour is more diffuse than the normal pigmentation. Changes in the lens and cornea, and the frequent scar of the iris assist the diagnosis.

After operation for cataract, Rollet has seen **débris of lens substance** deposited in the anfractuosities of the iris; these might be liable to undergo calcification. This phenomenon might play a part in the iridocyclitis following operations for cataract.

It is not unusual after surgical operations on the globe, to find **pellets of pigment** deposited on the lens capsule or iris (*vide infra*).

PATHOLOGICAL CHANGES

Pathological changes in the iris may be classified schematically as: vascular, exudative, pigmentary and atrophic.

Vascular changes, which accompany any iritis, are not particularly well seen with the slit-lamp. In subjects with brown

irides they may even escape observation. In blue or grey irides, dilated vessels, indicating hyperæmia, are seen.

To judge of the general colour of the iris, the lowest magnification (oc. 2, obj. 55) will be used.

In glaucoma it is not unusual to see the veins of the iris dilated, sometimes to a quite extraordinary degree. In one case of Vogt's, all the venules in the pupillary region were so dilated as to simulate hæmorrhages, and the dilatation had appeared in the space of a few days.

According to the researches of Koellner (*Ar. f. A.*, vol. xci. 1922, p. 181), dilatation of the vessels of the iris in glaucoma accompanies and precedes that of the episcleral network. This author considers that it is caused by atrophy of the iris stroma.

New vessels are often seen in cases of old iritis and iridocyclitis. Sometimes newly formed vessels leave the iris and form a network on the anterior lens capsule, especially if it has been covered with exudate.

Exudative changes manifest themselves first by the appearance of a haze in the anterior chamber with denser points which are generally pigmented. Later, precipitates are formed.

The slit-lamp has brought to our notice distinct formations which we call **nodules** to distinguish them from tubercles which are visible to the naked eye. *Nodules are produced by condensations of exudate and of cellular deposits usually without tissue formation.* They are seen especially in tuberculous affections, but may occur in other conditions.

Nodules are either mesodermic or ectodermic. The former consist of localised thickenings of the *mesodermic* layer. Conglomerations are formed by fusion of several nodules, particularly in the region of the collarette, but also in other parts. They become more or less vascularised.

Vogt has found that histologically they consist of a mass of epithelioid cells and lymphocytes. Neither caseation nor tubercle bacilli were found. Vogt did not succeed in producing an experimental tuberculosis by inoculation of fragments of an iris with nodules, into the anterior chamber of a rabbit.

When nodules occur in the peripheral parts of the iris they

cause the formation of a more or less extensive anterior synechia. After their resolution one frequently sees with the slit-lamp a more or less extensive obliteration of the angle of the anterior chamber by fibrous adhesions. Then, as there is usually atrophy of the iris stroma which deepens the anterior chamber, the free angle of the chamber becomes rounded and obtuse. We have observed this phenomenon in several cases of tuberculous irido-cyclitis.

Sometimes the nodules are superficial and appear only to be resting on the iris. In this case there is no vascularisation.

Ectodermic nodules are seen at the pupillary border in the form of whitish efflorescences, which appear to come from the posterior surface of the iris. They appear at each recurrence of the irido-cyclitis. Before the nodules, one sees a haze and "dust" in the anterior chamber, which would suggest that the nodules are deposits of inflammatory cells. This hypothesis is firmly established by the observation which we have been able to make several times on the same patient, that deposits are also formed on the pigmented layer which remains adherent to the lens after iridectomy. Moreover, Vogt has observed and drawn similar nodules found on the posterior surface of a portion of the iris, removed by operation.

The nodules at the pupillary border are generally too small to produce synechiæ, but if several nodules are situated close together a synechia may be formed.

They are rather transitory in character. After a few weeks or even after a few days, they may disappear. But they seem to disappear always more slowly than they have appeared.

The colour of the nodules is usually whitish, but they are often, as it were, powdered over with brown pigment granules.

Nodular irido-cyclitis, an affection which is curable though often recurrent, is not the same as the miliary tuberculosis recently described by H. Lagrange as a "tuberculous affection, with an inevitably fatal termination, accompanying or preceding tuberculous meningitis."

Pigmentary lesions consist especially of disintegration of the retinal pigment. The pigment border may lose its pigment

completely, or depigmented patches, visible by transillumination, may be produced on the posterior surface. These changes are more marked and less diffuse than purely senile changes, but it is clear that in an old patient it is impossible to say where one ends and the other begins.

After surgical interference on the globe, one sees pellets of pigment formed, some perfectly round, big enough to be visible to the naked eye, situated on the iris or on the lens capsule.

Atrophic processes modify the design and the relief of the iris, as is well seen, especially if the pupil is small. If these processes involve the whole surface of the iris in a diffuse manner, its radial structure is exaggerated, because the trabeculæ are thin, straight and disposed in radial fashion. Atrophy of the mesoderm allows the retinal layer to show through it, thus giving a dull greyish colour to the iris. The atrophied tissue itself becomes whitish.

Partial atrophies have been described, which begin and sometimes progress rapidly without having always an obvious cause. The tissue destruction may be so great as actually to produce *holes* in the iris. Sometimes it has been attributed to a chronic uveitis, glaucoma or syphilis.

In one case of Arnold's, no pathological sign other than the atrophy was observed. In a healthy woman of twenty-six, with a negative Wasserman reaction, a hole was seen in the lower quadrant of the iris. In it a few radial fibres, belonging, apparently to the posterior layer, still persisted. The pupil was irregular ; above it commencing atrophy was also seen. The history was absolutely negative.

Certain diseases which are not primarily ocular, such as diabetes, herpes zoster, variola, are accompanied by changes in the iris, which we shall consider briefly in so far as they concern the microscopy of the living eye.

Under the name of **vitiligo iridis** Müller has described grey patches in the irides of patients who have had variola. Löwenstein has examined two recent cases with the slit-lamp. In each case the right eye only was affected. About a dozen greyish, round, slightly depressed spots were seen on a back-

ground more deeply pigmented than themselves. There were always pigment granules in these atrophic areas, which occurred especially in the ciliary part of the iris. There were no other signs of old iritis. Both patients had had variola. One of them had also had syphilis. Löwenstein regards it as the result of an "enanthem" of the iris caused by the virus of variola.

Herpes zoster sometimes leaves permanent scars on the iris. In a case of Vogt's, four months after an ophthalmic herpes, a marked discoloration of one iris was seen. In the stroma were formed rounded pits in which an abundance of pigment was massed.

In a non-syphilitic patient of sixty-six years, who had had a left ophthalmic herpes six years previously, Duverger and Redslob observed marked atrophic changes especially involving the iris stroma, with almost complete disappearance of the sphincter. The pupil was slightly dilated and irregular. The outer part of the iris no longer reacted either to light or with convergence, and the inner part which reacted with convergence, responded to light with simple tremors. In the other eye the pupil reactions were normal.

Herpetic iritis is characterised by severe inflammation accompanied by hæmorrhages.

A patient of Löwenstein's, thirty-three years old, showed a papular infiltration in the region of the sphincter, dilated and tortuous vessels and multiple extravasations of blood. There were also several synechiæ and pigment deposits on the lens capsule and on the cornea.

Herpetic iritis seems to have a marked tendency to recur.

One finds sometimes, especially in *glaucomatous* eyes, *tiny cysts*, transitory in nature, situated on the pigment border and arising from the retinal layer. They are not, however, characteristic of glaucoma, and are found sometimes in normal subjects.

There occur small brown formations with rather translucent walls, situated anywhere on the pupillary margin and measuring about 1 mm. in length. They are often multiple. They burst spontaneously and disappear, leaving no traces.

Their nature is still obscure. Are they collections of fluid between the two retinal cellular layers, caused by an exaggerated secretion following the use of pilocarpine, which the majority of the patients have had ? Whatever they may be, care must be taken not to confuse them with the flocculus of the iris, which is stable and not as translucent as the cysts.

In **glaucoma,** migration of pigment is sometimes very marked. Part of the pigment remains adherent to the iris, more or less filling its crypts, the rest becomes fixed on the cornea or floats in the aqueous humour.

In advanced cases of glaucoma, atrophy of the iris stroma may be very pronounced. *Ectropion of the uvea* sometimes occurs in these cases and may involve a part or the whole of the pupillary border.

We have known for a long time histological changes in the retinal layer in **diabetes,** facilitating accumulations of pigment after operative interference on the globe. If one examines diabetics with the slit-lamp one sees generally only the usual senile changes. Sometimes, however, one sees changes which Vogt regards as pathognomonic of diabetes.

There is a considerable swelling of the pigment border which assumes a *spongy consistency*, its surface showing a multitude of tiny pits. In a patient of Vogt's, aged fifty-seven, and having, in spite of treatment, about 3 to 6 per cent. of sugar, this appearance remained unchanged for seven months.

These changes are not to be confused with the flocculus, which has a smooth surface and more irregular form and which is especially pronounced above the pupil and occurs more frequently in men.

Metzger has also observed changes which he attributes to diabetes. In a patient of forty-four, with 1·6 to 5 per cent. of sugar, a protuberance of the mesodermic layer was seen in the infero-nasal quadrant. Here the retinal layer seemed to be completely absent. The lacuna was surrounded by an opaque border. The lens was cataractous. This author considers that there is a breaking down of pigment, possibly with proliferation round the focus.

Dupuy-Dutemps drew attention in 1905 (*Annales d'oculistiques*) to an atrophy of the iris, with grey or green coloration in those subjects afflicted with **tabes** with Argyll-Robertson pupil. Lodato has studied several cases with the slit-lamp. His patients were aged fifty-six, fifty-two and fifty-eight years. The alterations consisted chiefly in atrophy of the mesodermic layer of the iris, with flattening of its surface (whence its dull colour), and in pigmentary migration. Dupuy-Dutemps thinks that these alterations are only seen when the reaction of the iris to light has been lost, and the motor troubles are more notable when the atrophy is pronounced. Lodato does not mention this point, but states that he has observed characteristic atrophy in cases in which the pupil was perfectly round and the pigment border intact. We note, without trying to explain the fact, that the six cases reported and figured by Lodato and Dupuy-Dutemps (*Soc. fr. d'opht., Mai*, 1924) all concern irides brown in the first instance.

In *leprosy* iritis may present two diagnostic features which Morax has pointed out. The iris may be covered with *small white points* (? small leproma), or there may be seen even *atrophic white striæ* contrasting with the iris tissue. In a case described by Morax there was an atrophic stria just below and concentric with the pupil in each eye.

Little white nodules have also been described by Espada, who finds them especially numerous in the neighbourhood of the sphincter (*cf.* Elliot, " Tropical Ophthalmology ").

CHAPTER VIII

THE CRYSTALLINE LENS

SPECIAL TECHNIQUE

In the normal condition, with a pupil of average size, the axial portion of the lens is accessible from the anterior to the posterior pole, inclusive. To examine the peripheral portions it will naturally be necessary to dilate the pupil to its maximum. By making the patient look upwards, downwards and to the side, the whole of the lens, so to speak, will be rendered visible, with the exception of the extreme periphery and the zonule.

Oblique illumination will be employed at the beginning of each examination. It will enable us to see, in the normal condition, the zones of discontinuity, the system of sutures, the remains of the pupillary membrane and of the hyaloid vessels. In the senile or pathological condition we shall see the remains of synechiæ, the relief of the adult nucleus, opacities, more or less empty clefts and vacuoles.

As an appreciable portion of light is reflected by the lens, we are able to examine the anterior layers by *transillumination* with the light reflected by the posterior layers. It is obvious that if the posterior layers are opaque a greater part of the light will be reflected, facilitating the examination by transillumination of the anterior layers.

By transillumination we shall see deposits on the anterior capsule, deposits that may be congenital—remains of the pupillary membrane, stars more or less pigmented, or pathological—remains of synechiæ and pigment granules of all kinds. We shall also see very well in grave cases of iritis or iridocyclitis, new-formed vessels creeping on to the anterior capsule. Now they will appear red, if they contain blood,

whereas by oblique illumination they are more greyish in colour.

In the anterior layers of the cataractous lens transillumination will reveal the frequent presence of droplets and more or less elongated vacuoles which may escape observation in oblique light, if the beam has not been well focussed. It will be the same with opacities and clefts. If a foreign body has traversed the lens we shall see, sometimes, in the track of the perforation, particles of the body.

We may have a *zone of specular reflection*, especially where there is a well-marked surface of discontinuity. Above all will this be the case at the anterior and posterior surface of the lens. At this level we shall see a characteristic shagreen. Zones of specular reflection will often appear at the anterior and posterior faces of the adult nucleus, more rarely at the anterior face of the fœtal nucleus. The size of the zone of specular reflection will vary according to the curvature of the surface considered.

The *angle of incidence of the beam* will be chosen according to the part that it is wished to examine. For the posterior pole of the lens the angle will be smaller the narrower the pupil. To obtain zones of specular reflection near the axial portion of the lens the angle will be equal to that which the direction of regard of the patient forms with the axis of the microscope.

The *wide beam*, and consequently the wide slit (when it is remembered that we use only the focal part of the beam), will be chosen for a general examination, and to look for the shagreen and its spherules, whereas, *if we wish to throw into relief the surfaces of discontinuity, we shall choose a narrow slit.*

The *magnification* will be the usual × 23 (obj. *a* 2, oc. 2).

The *localisation in depth* of any point has a special interest here, since we are often able to judge fairly approximately the date at which an opacity appeared. The consequence of the peculiar growth of the lens, uninterrupted and by layers, is that the central portions are the oldest and the peripheral

portions the youngest. In this way congenital opacities of the lens will be contained in the fœtal nucleus, which corresponds with the lens at birth, although they may retain a connection with the capsule. In this case we sometimes obtain cataract known under the name of *fusiform*, with or without *reduplication* (*vide infra*). As usual, the narrow beam will be of great value for exact localisation. It is in the examination of the

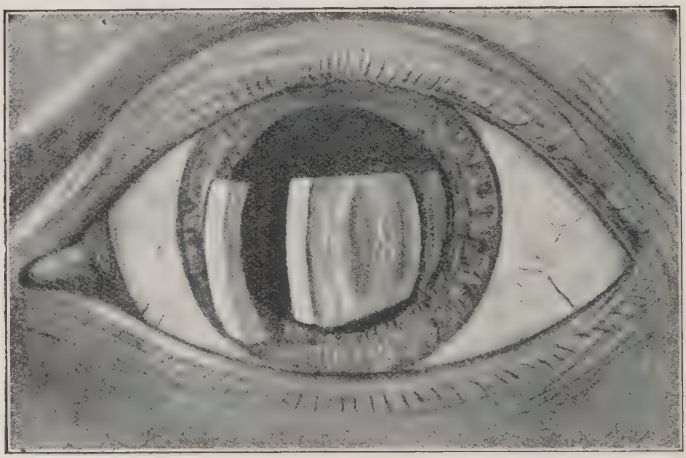

Fig. 32.—General view of the eye illuminated by a beam of moderate width coming from the left. On the left is seen the corneal parallelepiped, then a black space corresponding to the anterior chamber, then the " phantom " of the lens in which can be distinguished the dim central interval, the Y and ⅄ which delimit the fœtal nucleus anteriorly and posteriorly, and the surfaces of the adult nucleus. On the right we get a glimpse of some bundles of the vitreous.

lens that the method of localisation has achieved its triumph.

The *planes of reference*, which must obviously be represented as surfaces more or less convex, and which will be of service in localising depth, will be revealed by the bands which we see especially well in the narrow beam. Sometimes, also, *projected shadows* will allow a point to be placed. Thus an opacity which throws a shadow on the adult nucleus must be situated in front of it, at a distance proportional to the length of the shadow projected.

THE NORMAL LENS

Orientation.—Let us shine the luminous beam into a moderately-dilated pupil. Immediately we see, behind the dark, practically black space of the anterior chamber, the *phantom* of the lens appear, that is to say, the section of the lens cut by the beam shines out more or less brightly and stands out on a darker background (*cf.* Fig. 32).

The light which renders this phantom visible comes from regular and irregular reflection from the surfaces of discontinuity and dispersion of rays in the interior of the lens. To this we must add the rays produced by fluorescence, which phenomenon we may leave on one side. The light reflected regularly produces the images of Purkinjé. These phenomena interest us much less than the examination of the reflecting surfaces themselves (surfaces of discontinuity), which we shall see especially in the zones of *specular reflection* where there is a slightly irregular reflection.

The phantom of the lens shows two areas of maximum brightness, at the anterior and posterior faces of the lens, faces which we will call *anterior and posterior bands*. The substance of the lens is contained within these two bands. More deeply than the lens we encounter some bundles or pseudo-membranes of the vitreous. These reflexes are not fixed, but oscillate with the movements of the eye. This test is, however, superfluous in discriminating them from the bands of the lens.

Zones of Discontinuity.—The lens of a person of forty to sixty years presents the following bands :—

1. Anterior band of the lens.
2. Anterior band of disjunction.
3. Anterior band of the adult nucleus.
4. Anterior peripheral band of the fœtal nucleus.
5. Anterior central band of the fœtal nucleus.
6. Posterior central band of the fœtal nucleus.
7. Posterior peripheral band of the fœtal nucleus.
8. Posterior band of the adult nucleus.
9. Posterior band of disjunction.
10. Posterior band of the lens.

By leaving on one side the bands of disjunction especially visible with a narrow beam, and neglecting the peripheral bands (exterior), often poorly marked, of the fœtal nucleus, we obtain the principal bands which every lens shows at the end of its growth.

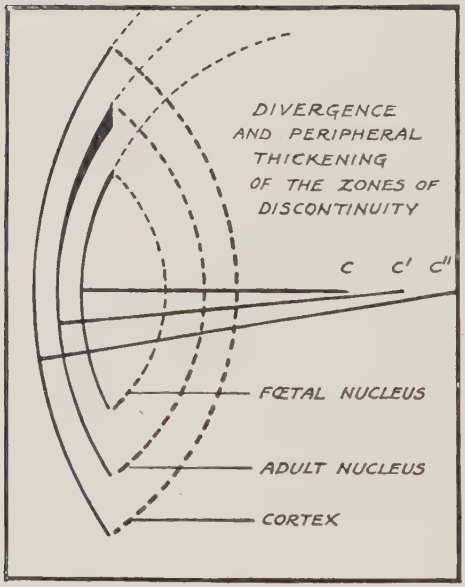

FIG. 33.—Diagram representing a sagittal section of the lens with the principal surfaces of discontinuity marking off an adult nucleus, and in its interior a fœtal nucleus. C, C′, C′′ represent the various centres of curvature of the surfaces.

(*a*) Anterior and posterior bands of the lens.

(*b*) Anterior and posterior bands of the adult nucleus.

(*c*) Anterior and posterior bands of the fœtal nucleus.

The fœtal nucleus corresponds to the lens at birth. By becoming surrounded with substance added to it there develops, towards the end of the growth of the individual, the adult nucleus. We reserve the name *cortex* for those layers which form subsequently up to the date of death.

The bands of discontinuity are more or less pronounced according to the individual. Not only does their average luminosity vary, but also their relative luminosity. In some the fœtal nucleus appears almost homogeneous and dark, in others we are able to distinguish two anterior and two posterior surfaces, more or less marked. In the same way the adult nucleus is sometimes very distinct, and at another time distinguished with difficulty.

As a general rule, the older the *subject, the more marked are the bands.*

What, with a low magnification, appears to be a single band is often formed of several surfaces of discontinuity very near to one another.

The actual centre of the fœtal nucleus is the most homogeneous portion of the lens and that which shows the least optical density. It, therefore, appears darker and constitutes the *central interval.*

The curvature of the bands is not the same throughout. *The further the bands from the central interval, the more their curvature diminishes* (*cf.* Fig. 33).

Further, it is noticed at first sight, that in proportion as the surface is separated from the ideal centre of the lens, its radius of curvature increases more than the space between the surface and the centre of the lens. In other words, the centres of curvature do not coincide : *the layers are not strictly concentric.* It is possible to express this differently by saying that the lens becomes continually flatter as age advances. This phenomenon, which tends to reduce the refractive power of the lens, is usually almost exactly compensated by the increase of the index of refraction of the nucleus.

It is probable also that each surface of discontinuity is not exactly spherical, its radius varying from point to point. We do not know anything precisely about this. The flattening of the lens is rather *phylogenetic* than *ontogenetic* and somatic. As Rabl has shown, the higher the species in the evolutionary scale the flatter the crystalline lens.

From the histological point of view the flattening is caused by the *thickening of the fibres towards the periphery of the lens.* This thickening in calibre of the fibres causes a *peripheral divergence of the bands of discontinuity.*

It is hardly necessary to mention that the curvature of the posterior bands is greater than that of the anterior.

Sutures.—In the interior of the fœtal nucleus the substance is homogeneous and there can be distinguished neither fibres nor sutures. In the rest of the lens there is seen a system of sutures especially marked at the level of the surfaces of dis-

continuity and in the axial parts of the lens. At the anterior surface of the fœtal nucleus the suture is in the form of a Y. At the posterior surface the suture is inverted (⅄). These two figures are of great use for topographical orientation. It may be noted in passing that all the classical descriptions give these two sutures an exactly opposite arrangement!

The further the layers of fibres from the fœtal nucleus, the more the sutures become branched and complicated, so that the sutures of the cortex are most complicated. There exist, naturally, anatomical connections between the sutures of different age, which may be verified by narrowing the beam. On the other hand, there is never a direct fusion between an anterior and posterior branch, and the figures of Hosny, among others, which represent this, rest upon manifest errors of interpretation.

Fœtal Nucleus. This is limited anteriorly by the Y, less easily seen than the ⅄, which marks its posterior face. The limbs of the sutures are almost rectilinear. Their length is on the average from 1 to 2 mm. They may be branched at their extremity. The branching begins at first by a bending at the extremity of the limb. The extremities of the lens fibres are inserted into the sutures and form there a delicate design in parallel lines. The fibres are much better seen when the subject is aged. The sutures may appear dark upon a clear ground, or, inversely, clear upon a dark ground, depending upon the age of the subject and the method of illumination.

At the level of the star shaped figures a zone of discontinuity is noticed which is not very sharply marked off and which extends sagittally on to a fairly deep space, giving to the two zones the appearance of two coffee beans or diplococci separated by a dark interval (*central* interval).

These zones of discontinuity are often divided into two, so that it is possible to distinguish two *central* (interior) surfaces from two *peripheral* (exterior) surfaces. In this case the design of the sutures, in the form Y or ⅄, is always more pronounced at the level of the peripheral surfaces. According to Vogt, the peripheral zones date from the first few months of life.

In advanced age, and rather exceptionally, the anterior sur-

face of the fœtal nucleus may develop a peculiar *relief* with a pattern of sutures more or less sharp, recalling the appearance of the adult nucleus.

Adult Nucleus.—Towards puberty a certain number of new layers have surrounded the fœtal nucleus, forming with it the adult nucleus. Some years later there is seen to appear little by little under the capsule a zone of discontinuity delimiting the surface of the nucleus. We reserve the name cortex for the substance which will form ultimately between the adult nucleus and the capsule.

The surface of the adult nucleus is rarely smooth, *but exhibits a peculiar relief* rather suggesting plastic reproductions of geographical maps. Vogt and Lüssi have thoroughly studied the relief of the adult nucleus, which is, however, perceptible, in a pronounced case, with the aid of a simple loupe.

This formation of relief is a senile phenomenon, which we will study later on.

The bands of the adult nucleus are more or less pronounced, according to the individual. Often they are zones of discontinuity rather than true surfaces. In accordance with the growth of the cortex, the distance from the bands of the nucleus to the corresponding bands of disjunction increases with the age of the individual. When accessory zones of discontinuity form in the deep cortex, or when the peripheral band of the fœtal nucleus is exceptionally well marked, it may be difficult to place the band of the adult nucleus, especially if the relief is wanting. This name is reserved for the most luminous band in the anterior part of the lens placed behind the anterior band of disjunction.

Cortex.—This includes the superficial layers of the lens between the capsule and the surface of the adult nucleus. These are the youngest layers, that is to say, the most recent, the growth of the lens taking place, as we know, by the apposition of new fibres.

The researches of Vogt and Gallati have shown that the *cortex increases continually in thickness with age*, and in a regular manner. The two lenses show the same configuration and the two sexes behave similarly.

The relative thickness of the cortex (anterior + posterior) compared to the adult nucleus is given by the following figures :

Age of Subject.	Cortex.	Nucleus.
16 to 19	0·178 ..	0·822
20 ,, 29	0·207 ..	0·793
30 ,, 39	0·256 ..	0·744
40 ,, 49	0·287 ..	0·713
50 ,, 59	0·309 ..	0·691
60 ,, 69	0·319 ..	0·681
70 ,, 81	0·325 ..	0·675

These values have been measured directly on the living and compared to a total thickness of the lens equal to 1.

We shall see later that the phenomena of senility of the lens show themselves chiefly at the level of the deep layers of the cortex.

The sutures of the fibres are more complicated in the cortex than in the nucleus. In a general way, they have a radial direction and are a dozen in number. They are united two by two, forming a gothic arch, the point of which is directed towards the centre of the lens. The principal sutures leave the apex of each angle, reuniting in an irregular way towards the axis of the lens roughly forming the figure .

The cortex is not absolutely homogeneous, especially in aged persons, and the narrow beam sometimes throws into relief several bands of discontinuity in its interior. It often shows very small punctate opacities which must be regarded as "physiological," and which are not directly connected with senile cataract.

Shagreen.—The shagreen is seen in the anterior and posterior zones of specular reflection of the lens. It is produced by the light reflected slightly irregularly by the capsule, endothelium and superficial fibres and then appears *clear upon a dark background.*

Again, with the highest magnifications, the capsule appears

perfectly smooth and nothing is seen of the depressions described by Anselmi, after an examination *in vitro*, and to which Toulant believed that a role in the production of the shagreen might be attributed.

The reflections of light which produce the shagreen do not take place at one surface only, but chiefly in the space contained between the capsule and the band of disjunction.

We see more or less well in the shagreen the design of the lens epithelium, better still, that of the fibres and sutures and in certain circumstances peculiar bodies: the *spherules of the shagreen.*

These spherules are bodies of 20 to 60 microns in diameter, seen better in a diffuse illumination than in focussed light, and more frequently in the old than in the child. They are chiefly, but not only, arranged like a crown placed between the middle and outer thirds of the area of the pupil dilated to the maximum. According to Vogt, they sometimes look like holes made with a punch.

In the neighbourhood of the sutures, which remain dark, the design of the shagreen is composed chiefly of short more or less parallel lines which evidently correspond to the lens fibres. Elsewhere, and chiefly towards the centre of the surface of the lens, the design is in the form of a mosaic with irregular hexagonal elements. These elements must not be confounded with the epithelial cells, which are much smaller.

Shagreen presents the same appearance in different individuals, and variations are slight. It is slightly more marked in adults than children, but has no relation to senile cataract.

In senile cataract, in proportion as opacification and vacuolation approach the capsule, the shagreen becomes modified, fades, and finally disappears.

Shagreen is well seen, especially in diffuse light, which strikes the lens under a large angle of incidence.

At the anterior surface of the lens, as well as the posterior, the zone of specular reflection shows a peculiar *lustre*, which it is important to know and distinguish from the poly-chromatic lustre (iridescence), which is the first sign of complicated

cataract. There is no decomposition of light except in pathological conditions.

The lustre of white light is due in part to the fact that in binocular vision the light areas that one eye sees do not coincide exactly with those seen by the other, in part also to the circumstance that the multiple reflexes, which constitute the zone of specular reflection, are easily displaced by movements of the observer and subject. The lustre is also facilitated by the multiplicity of reflecting surfaces, as are seen in minerals.

The slit-lamp also gives important information as to the *total thickness of the lens*. It is seen that it varies slightly from one individual to another and that it increases with age. To be able to compare the thickness of the lens in different persons, it will be necessary always to use the same angle of incidence of the beam (for example, 30°) and the same angle of observation (for example, 10°, measured from the optic axis, the eye fixing a point directly in front of it).

CONGENITAL ANOMALIES

Remains of the pupillary membrane, in direct connection with the lens, show themselves under two forms.

Arcades and festoons of a delicate design are occasionally seen occupying the peripheral portion of the surface of the lens. Sometimes we have the impression that there is an opacity in the surface of the capsule, or rather a fine membrane stuck down upon the lens. These relics may coincide with *filamentary or web-like remains*, stretching from one part of the collarette of the iris to another. They are not pigmented, but whitish in colour.

Much more frequently than these festooned relics, in about one-third of all individuals, *isolated remains* are found. They have an amorphous, or often a *stellate* form. *They are always more or less pigmented.* In a general way, their colour corresponds with that of the iris.

These star-shaped opacities have an average size of 40 to 60 microns and are arranged anyhow upon the anterior capsule.

Rarely they occupy a line concentric with the pupil. Three forms may be distinguished.

The first is massive; the pseudopodia are short. The second is more delicate; the pseudopodia are more numerous, longer, and anastomose frequently with those of neighbouring stars. Finally, yet more rarely, the pseudopodia end in regular swellings, like the foot of a frog.

According to Rumbaur, these star-like remains are found in 35 to 40 per cent. of cases. In two-thirds of those affected they are bilateral. It appears that they become more rare in old age, and it is supposed that they may disappear.

Although star-like remains may sometimes be so numerous that they are visible to the naked eye, the vision is never affected, because the axial parts of the eye remain free.

Small remains of an annular form, thick on one side (Rumbaur), are very rare.

Arlt has found these relics again in a histological examination and has proved that each star has the form of a cell with numerous pseudopodia containing an oval nucleus which stains badly. A fine brown pigment was scattered regularly throughout the cell. The thickness of the cell amounts to a sixth of that of the capsule of the lens, its length to six diameters of the epithelial cells.

Remains of the posterior capsulo-pupillary membrane are rarer than those of the pupillary membrane. *Their peculiarity is that they are not pigmented.* They present less interest than the remains on the anterior surface of the lens, because there is no risk of confusing them with exudative pseudo-membranes.

From 1 to 2 mm. to the nasal side of the posterior pole of the lens we can almost always find a relic of the **hyaloid artery** in the form of a whitish corkscrew. The anterior end of the artery is fixed to the lens capsule by a white plaque of varying size, whereas the other end floats freely in the vitreous.

We shall study the relics of the hyaloid vessels later on.

The best-known anomaly in the shape of the lens is *lenticonus*.

Cases of **posterior lenticonus** have been studied with the slit-lamp by Vogt and by Riedl.

The case reported by Vogt occurred in a woman of thirty-nine years whose left eye was absolutely healthy. With the other eye the patient counted fingers at 1 metre. The lenticonus consisted of a circumscribed prominence in the form of a truncated funnel situated exactly at the posterior pole of the lens and projecting into the vitreous. At the place where the prominence began there was seen a very bright annular reflex caused by a reflecting surface having its convexity forwards. The space contained within this reflex exhibited a porous cataract of a radiating type at the periphery, and a concentric structure towards the middle. The hyaloid artery was inserted directly into the side of the cone, on the nasal side. This fact shows clearly that in the cases studied the lenticonus is not produced by the traction of the hyaloid artery, as has been suggested. It is also remarkable that in Vogt's case the fœtal nucleus was of normal form, which indicates that the lenticonus arose at the onset of extra-uterine life.

Under the name of *anterior axial embryonic cataract* Vogt has described a form of opacity that in all probability is congenital. The opaque areas are extremely small, hardly reaching one-tenth of a millimeter in diameter. They are multiple and consist of *very white points contained within a whitish halo. The opacities are always situated in the immediate neighbourhood of the anterior* Y, in a fairly thin layer, and if they are not exactly in the coronal plane of the sutures, they are rather in front of it than behind.

This type of cataract is found in a quarter of those examined, sometimes on one side only, sometimes on both. It is not necessary to dilate the pupil for the examination. When the opacities are sufficiently numerous they make a figure in the form of the Y. Similar changes may be seen in domestic animals. Axial embryonic cataract is *essentially stationary*, and its only senile modification is to become a little more yellow on account of the selective absorptive power of the interposed lens matter. Although the opacities have sometimes a crystalline

glitter, it is rare for them to produce an iridescence like cholesterin. They are too tiny to affect vision. According to Vogt, anterior axial cataract develops about the fourth month of intra-uterine life.

Opacity of the sutures is evidently allied to the preceding type. Here, however, it may be either the anterior Y or the posterior, or even both that are affected. The opacities are compact or snowy and mark fairly well the shape of the fœtal sutures, sometimes even their ramifications. More rarely, each suture is, as it were, reduplicated, having an anterior and posterior part similar in shape. If the sutures differ in thickness, the thinner appears bluish and the thicker yellowish. This form of cataract develops either just before or just after birth. It has often been described under the name of *stellate cataract.*

Congenital **anterior capsular cataract** consists of one or more opacities situated at the level of the capsule of the lens or in contact with it. Pure capsular opacities are rare. There are two methods by which they may be recognised. By reducing the width of the beam to its minimum and examining the section under a sufficient angle of observation, it will be seen that the affection does not extend into the substance of the lens, but forms part of the lens capsule. Examining the opacity in the zone of specular reflection of the anterior surface of the lens, it will be seen surrounded by a halo, dark *not shagreened*, which indicates that the opacity modifies the curve of the capsule (Vogt's sign).

Capsular opacities may also be very white and not situated exactly at the anterior pole of the lens. They are generally small, scarcely exceeding 1 mm. in diameter.

Lowenstein and Riedl have shown that when there are opacities in connection with remains of the pupillary membrane, it is sometimes possible to prove the presence of brown pigmented granules beneath the lens capsule.

The insertion of the hyaloid artery into the posterior surface of the lens is sometimes so extensive in area that it is possible to speak of *capsular cataract*, or, since the artery is inserted near

to the posterior pole, of *posterior polar cataract* (*cataracta polaris spuria*).

Nevertheless, there are posterior cataracts that seem to be independent of the hyaloid artery. They are, however, much less frequent than the anterior. They habitually complicate posterior lenticonus.

Anterior polar cataract is usually congenital. That it is congenital is often proved by the presence of remains of the pupillary membrane inserted into the anterior pole of the lens and to the iris collarette and varying from a simple filament to a complex network of tissue. In these cases we have constantly observed a decoloration of the iris. The inflammatory origin of opacity of the lens is admitted when it is connected by a filament, not to the collarette but to the pigment border of the pupil. It becomes then a question of congenital remains or synechiæ. At other times traces of a keratitis in the form of a corneal nebula will be noted, which, as is known, need not be central.

An optical section passing through the polar opacity shows that it extends more or less deeply into the interior of the lens, according to the date at which it appeared. Sometimes there are two identical opacities separated by a more or less clear layer (*reduplication*). At other times the opacity shows a well-marked concentric structure. The opacity may also stand out into the anterior chamber, the picture of a *pyramidal* cataract.

The optical section occasionally brings out an extremely interesting phenomenon : *the fusion, in the opacity, of several bands* (surfaces of discontinuity). In this case the lens is umbilicated in its centre and, if the cataract affects both poles, shows a considerable thinning in the sagittal axis.

The peculiar method of growth of the lens explains this. A cataract may, in certain cases, impede the addition of new layers, and then is seen the fusion of several bands. Again, if growth takes place normally, the new layers, which are clear, may divide the opacity into two, and then *reduplications* are formed.

A polar opacity may be very small indeed and measure less than a tenth of a millimetre in diameter.

From the point of view of heredity, the anterior polar cataract is transmitted as a *dominant Mendelian character*.

According to Vogt, it originates towards the end of intra-uterine life, which renders the hypothesis of an error in development at the time of the formation of the lens vesicle much less probable. One other piece of evidence weighs heavily against this early origin: the constant integrity of the embryonic nucleus.

Zonular cataract gives with the slit-lamp interesting and diverse pictures.

The pupil is dilated as a preliminary and the lens is first examined in a diffuse lateral illumination, and then in the optical section.

One class only of zonular cataract is congenital; the others are developed at the beginning of extra-uterine life.

The opaque disc of the cataract corresponds more or less exactly with the fœtal nucleus, and is embedded in the clear substance which contains those angled peripheral opacities that have been long known under the name of "*riders*." A careful examination shows that these so-called "riders" are often situated outside clear gaps in the opaque substance, which has caused Vogt to entertain the view that "riders" are portions of the opaque substance detached from it by fibres recently inserted and which have remained clear.

The narrow beam sometimes allows it to be stated that in the interior of the cataractous zone, there occurs a disc-shaped opacity which is exactly centrally placed. Also, there is often an anterior or posterior polar cataract. Sometimes, also, the system of sutures is particularly opaque and white and sharply cut off from a less cloudy layer. This appearance forcibly recalls what is seen during opacification, *in vitro*, of the lens in saline solutions. "Riders," which may be very numerous, have a length and thickness which is very variable.

In high magnification the opaque zones are seen to be composed of very fine, dense spots.

In the opaque portions, or in their neighbourhood, the presence of coloured and brilliant crystals in the form of needles is often encountered.

In **Mongolian idiocy** it is only rarely that cataract is present at birth. Although congenital in origin, it is only developed towards the fifteenth year. It has already been observed macroscopically by English authors (Ormond, Leeper, etc.). Van der Scheer has drawn attention to the fact that the anterior sutures of the fœtal nucleus are often opacified.

In a personal observation the sutures were absolutely free. The subject, a girl of seventeen, had a convergent strabismus, epicanthus and very short palpebral fissures. The vision in

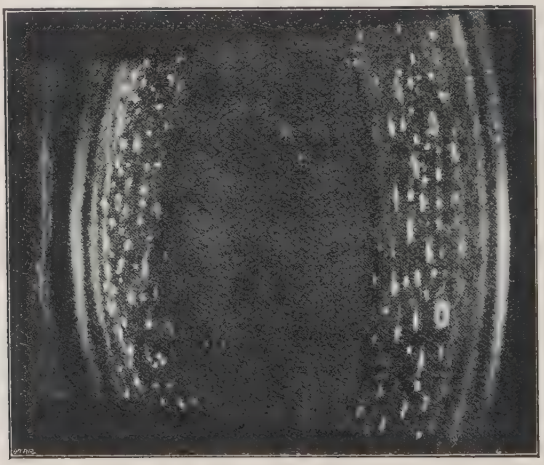

Fig. 34.—Cataract in a case of Mongolian idiocy.

the right eye was 6/24 with — 3 Ds., in the left 6/60 with — 5 Ds. The bands of discontinuity were fairly clear. The opacities were multiple and of two kinds : *flattened opacities, yellow and blue in colour*, of the same type as blue cataract, and *fine crystalline opacities showing green and blue iridescence*, resembling those of post-operative tetany and of myotonia atrophica. The fœtal nucleus was free of opacities, which were spread in disorderly fashion throughout all the layers in front of and behind it, with the exception of the most superficial.

Under the name of **floriform cataract** we have described an affection, which is rather rare, and is certainly a congenital

malformation. The cataract is composed of a certain number of opacities, 30 to 100. Each opacity is itself formed of elements of a round *annular* form. By grouping several elements, 2 to 20, there arises a series of circular opacities, arranged like a flower, the apparent size of which varies from 0·5 to 0·75 of a millimetre on an average. The opacities are

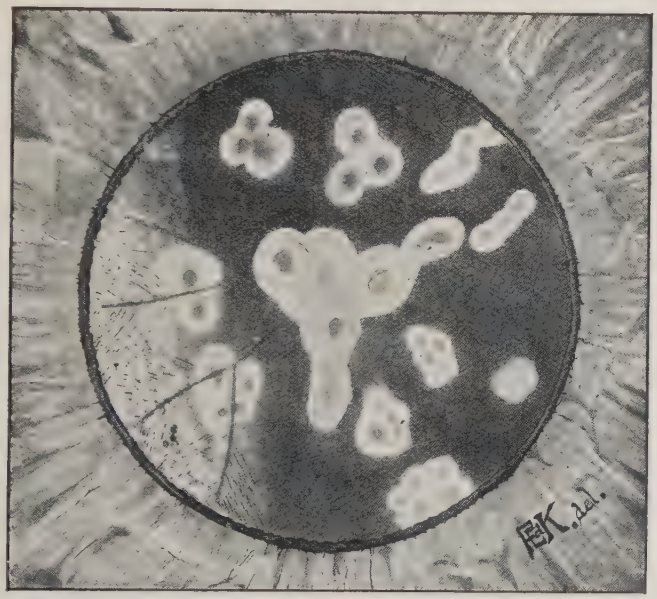

FIG. 35.—Front view of a floriform cataract. Diffuse light coming from the left. On the left is seen the anterior shagreen of the lens in which some sutures shine through. The opacities are chiefly grouped around the sutures of the fœtal nucleus.

flattened, occasionally shaped like a mulberry, but sagittally have no connection among themselves. *The cloudiness is more dense at the periphery than* at the centre, and the opacities, examined by transillumination, appear diaphanous. Their colour is whitish or bluish in oblique light, yellowish in reflected light. They are sometimes lustrous.

The arrangement of the floriform opacities is characteristic (*cf.* Fig. 35). They are grouped towards the axial portions of the lens, and notably in the immediate vicinity of the anterior

and posterior sutures of the fœtal nucleus, sometimes, in their arrangement, taking on the form of a Y. Nevertheless, cortical opacities are sometimes encountered, which seem to have developed several years after birth.

In one family the mother and four children were affected. The maternal grandfather most likely suffered from cataract. The anomaly seems to behave as a dominant Mendelian character. The corrected vision was on an average 0·1 to 0·4. Some were myopic, and three of the children showed campto-dactylia. In short, this cataract seems to be an intermediate form between cataract of the sutures and *coronary* cataract, which we shall meet later on.

Among rare forms of congenital cataract it is proper to mention a *white stippling of the fœtal nucleus* or of the centre only (*cataracta centralis pulverulenta*). It is often found that these opaque dots are surrounded by a less dense halo, the appearance of which we have already met in the anterior axial embryonic cataract, and which indicates, according to Vogt, the intra-uterine origin of this opacity.

More rarely again there will be seen denser opacity, occupying the centre of the lens, and connected by a prolongation, with the capsule (*fusiform cataract*).

We distinguish also, among less frequent congenital opacities, *stippling in the form of a disc or ring*, which may or may not coincide with an embryonic anterior axial cataract, and which is situated at this level. We have seen, in several cases, a disciform cloudiness surrounding an opaque anterior suture.

Finally must be mentioned, as probable congenital forms, the curious **crystalline cataract** more or less allied to the very rare *Spiesscataract* (lance cataract) of Vogt.

SENILE MODIFICATIONS

Modern research has caused ordinary cataract (grey, senile) to be considered as the result of purely senile changes, gradually coming on at a period determined less by exogenous factors than by heredity.

The slit-lamp, obviously, exposes these modifications much

sooner than other methods of investigation, so that it is often possible to speak of *presenile* changes. At their onset the vision is in no way affected, especially if the site of the lesions is peripheral. It is a daily experience to find, *if the pupil is dilated*, changes amply meriting the name of cataract in those who do not complain of the slightest trouble with sight. In ocular microscopy the term "cataract" is employed merely in the subjective sense of *opacification of the lens visible with the slit-lamp*, or more exactly, *localised increase in optical density*. We know that in physics optical density is expressed by the relation of the logarithm of the intensity of the incident beam divided by that of the intensity of the transmitted beam. Thus the phenomena that we establish with the slit-lamp are not on an equal footing with *sclerosis* of the lens, if we reserve this name for the cause of the diminution of the elasticity of the lens, which expresses itself physiologically by presbyopia.

It is known that the *sagittal diameter* of the lens increases continually with age, the lens increasing in volume and weight and the anterior chamber being obliterated insensibly. If we wish to study this point it will be necessary always to use the same incidence of the luminous beam and the same angle of observation.

The *fluorescence* of the lens, increasing considerably with age, may be considered as a senile process. We leave this on one side, because the slit-lamp and the usual sources of light do not bring out this point particularly.

The increase of internal dispersion (*diffuse reflection*) of the light may be observed in the optical section, if it is possible to compare the lens of a child with that of an old person. Even if in advanced age there are no circumscribed opacities, the increase in optical density gives to the lens a more or less marked opalescent appearance. To judge of diffuse reflection it is necessary to project the beam in such a manner as to avoid the zones of specular reflection in the bands of discontinuity, because the light thrown back by the zones of specular reflection is not absolutely diffuse, but is submitted to a more regular reflection.

In the aged the zones of discontinuity of the lens are much better marked than in the child.

A **yellowish coloration** of the lens accompanies an accentuation of the internal dispersion of light. This yellow colour is in great part produced by the fact that the rays dispersed are of short wavelength, which gives the *warm* tones, while those transmitted are of greater wavelength.

It is remarkable that it is the posterior cortex which appears to be the most yellow, for the reason that the rays transmitted to the observer have been doubly filtered, viz., on entering and leaving the lens. The apparent golden yellow tint of the posterior layers of the lens often reaches a striking intensity in old people. Occasionally the tint of tyrosine or other similar body may be added to the yellow coloration. We find this yellow colour with such frequency with the slit-lamp that we must admit that the **black cataract** of older observers is nothing more than an extreme form of this senile process.

We have referred above to the **spherules of the shagreen.** They are especially frequent and numerous in the old, and can only be seen when the shagreen is brought to a focus. That is to say, they are situated in the most superficial layers of the lens. Depending upon the direction of the light, the spherules appear with tiny reflexes which betray their spherical shape, or as black holes which are perfectly round and of an average diameter of 20 to 40 microns.

The **formation of relief** in the interior of the lens is a phenomenon accessible only to the slit-lamp. It has no relation to lens opacities, but is a peculiar modelling of the surfaces of discontinuity. With age the anterior surface of the adult nucleus becomes more luminous and the anterior band of the nucleus may reach and surpass the luminosity of that of the lens. At the same time there is observed on the surface of the adult nucleus the formation of a peculiar relief, **the sutures forming a projection forwards, and also elongated crests,** having roughly

the form with branches, each branch measuring about

0·2 mm. in diameter. We can obtain a clear idea that these are true projections by illuminating the pupil at one time from the right, at another from the left *with a large angle of incidence* and with a diffuse light. The shadows produced recall those seen on the moon, but they are less sharp.

There are also seen round protuberances, situated in the axial parts of the lens, gradually fading off towards the periphery. The length of the crests marks out as a projection the design of the lens fibres, often with great sharpness. There is reason to suppose that the hemispherical projections are produced by a collection of fluid (vacuoles).

The formation of relief is more marked in the axial parts of the lens than at the periphery. This fact facilitates the distinguishing of relief from senile opacities, which are usually peripheral. Again, *the visual acuity is not altered by the presence of relief even when very pronounced.*

The cortex may remain clear in front of the relief, or it may be affected so as to efface it more or less. Lamellar separation (*vide infra*) sometimes seems to have a share, also, in the modelling of the adult nucleus.

The following table, borrowed from Vogt and Lussi, shows the frequency of relief :—

Age of Subject.	Number of Subjects.	Pronounced Relief.	Slight Relief.
1 to 10 years . .	7	—	—
10 ,, 20 ,, . .	84	1	—
20 ,, 30 ,, . .	116	4	9
30 ,, 40 ,, . .	83	3	12
40 ,, 50 ,, . .	87	26	19
50 ,, 60 ,, . .	87	32	27
60 ,, 70 ,, . .	92	24	20
70 ,, 80 ,, . .	67	10	5
80 ,, 90 ,, . .	5	1	—
	628	101	92

Among these 628 subjects there were further 75 cases of coronary cataract, 75 other forms of opacity, 20 cases of nuclear cataract, and 83 cases of negligible opacity.

When the relief of the adult nucleus is sharp on the anterior surface it is often possible to discover *that it exists also on the posterior surface.* Naturally the relief is here reversed and the crests of the sutures project backwards.

FIG. 36.—Diagram showing the formation of clefts in the cortex. In *a*, front view; in *b*, optical section; *bd*, anterior band of disjunction; *na*, anterior band of the adult nucleus. In *a*, on the right below, a slit is developing at the expense of a suture of the cortex, above, two clefts separating the fibres themselves. In *b*, the clefts present themselves as irregular holes. The lower one reaches the anterior capsule, across the band of disjunction. The upper divides the anterior band of the adult nucleus and respects the band of disjunction.

In the same way *the fœtal nucleus may show a similar relief.* But here the sutures are more simple and in the form of a Y. The surface is less bossed than in the adult nucleus and shows a greater curvature. Sometimes the relief is slightly marked in the adult nucleus and more pronounced in the fœtal nucleus. But this is very exceptional. The formation of **clear clefts** in the interior of the lens is a senile process related to cataract. We say "clear clefts" (German: *Wasserspalten*), because the interior of these fissures has a less optical density than that of

the rest of the lens, so that focal light causes them to appear dark, whereas by transillumination they appear perfectly transparent. In an early stage they are full of a homogeneous fluid which probably impregnates their walls, causing them to become more or less opaque. The clefts form sometimes, at the expense of the sutures, by their opening out, sometimes by the separation of the fibres (*vide* Fig. 36). They occur usually in the cortex, and occasionally in the interior of the adult nucleus, and the *fissured cataract* of the older authors was probably a very pronounced form of formation of clefts. One observation of clefts in the fœtal nucleus, made by Polack, is called by him dehiscence of a zonular cataract. It is interesting to notice that this author has recognised the real position of the Y, but as it differs from the classical description, he takes it to be " abnormal " in the two lenses.

The **opening out of sutures** is seen also in lenses, *in vitro,* placed in saline solution, even hypertonic. It is seen more especially after a few hours in distilled water. It arises always at the point of fusion of two sutures by the formation of a little fontanelle, which soon increases in size.

A table of statistics collected by Pfeiffer of 111 persons of any age showed the absence of clefts in 80 subjects, that is 72 per cent., and their presence in 31, that is 28 per cent. Of the 31 persons affected, in 13 only one eye was affected, and in 18 both.

Clear clefts appear after fifty years of age, and, it seems, *a little earlier in women than in men.*

They occupy most frequently the anterior cortex, more rarely the posterior. Among the observations of Pfeiffer they were seen in 42 per cent. of cases in front and behind, in 53 per cent. only in front, and in 5 per cent. behind only. Their exact site is determined by the aid of the narrow beam (*cf.* Fig. 36, *b*). In the optical section they have the appearance of black irregularly-shaped spaces, which are very puzzling for an uninitiated observer. Sometimes they may be seen to reach the capsule itself across the anterior band of disjunction. They are usually arrested at the anterior band of the adult nucleus.

Finally the clefts become filled with rounded corpuscles (droplets of myelin ?), *which then give them the appearance of opacities.* This opacification of the lens takes place very gradually.

Most often, *when we find clear clefts, we also see different forms of senile opacities.* The former usually precede the second.

Hess has shown that the first stage of naphthalin cataract in a rabbit is characterised by the appearance of multiple clear clefts.

Exceptionally there is encountered in young people an isolated **vacuole,** situated more or less deeply in the lens.

Illuminated by a beam which is well focussed, the vacuole shows an anterior and posterior reflex, and behind it is seen the track of a shadow.[1] These characters are of such clearness that there is no doubt possible as to the nature of the vacuole.

The vacuoles may remain stationary for many years. With age they often multiply ; at the same time lens opacities make their appearance. In ripe cataract there forms under the capsule a veritable carpet of droplets : *the subcapsular layer of vacuoles.*

More rarely one or two large vacuoles are seen, reaching 1 mm. in diameter, situated sufficiently superficially to cause a prominence in the relief. In some cases we have seen the shagreen preserved on the vacuole, which shows that the lens epithelium, at least, and possibly some layers of the lens are raised by the fluid.

Lamellar separation is a senile *phenomenon intimately connected with cataract.* It is situated in the cortex, in the middle or deep layers. In the latter eventuality, if the microscope be focussed upon the relief of the adult nucleus, we see the lines of separation more or less sharply.

Separation shows itself by a series of parallel lines similar to the fissures in glass, running upwards and outwards from the infero-nasal region. But they are also seen in other directions. More rarely there occur two or more systems of parallel lines

[1] *Cf.* Koby : " Les ombres portées en microscopie oculaire," *Arch. d'oph.*, 1924, p. 271.

cutting one another at different angles. An arrangement of the lines concentric with the pupil is also unusual. Lamellar separation seems to develop under the influence of hydration of the lens.

When the lines of separation cut a suture, they are not changed in direction, but are continued upon the other side.

The visibility of the lines of separation depends upon the direction of the light, and gives a maximum for an incidence which can be determined.

Schild finds, in 111 persons of all ages, that separation is not seen before the fiftieth year. He finds it :—

From	50	to	60	years	in	7	per cent. of cases.
,,	60	,,	70	,,		18	,, ,,
,,	70	,,	80	,,		32	,, ,,
Above			80	,,		50	,, ,,

They are seen earlier in women than in men.

Among those affected, the condition is seen in 27 per cent. in only one eye and in 73 per cent. in both eyes. *Lamellar separation is three times more frequent in the anterior cortex than in the posterior.*

When lamellar separation is present, opacities, usually of the cuneiform type, are almost always found (*vide infra*). Very frequently, in adult lenses, we find *very fine punctate opacities situated in the cortex.* This observation is so common that these opacities must be looked upon as normal (*cataracta punctiformis*). It is much more rare to meet in the *adult nucleus* little opacities *in the form of a spiral.* These white spiral opacities are always multiple and have no direct relation with senile cataract.

Punctate opacification of the sutures of the anterior cortex is a comparatively rare process. There may be seen a considerable number of very fine, grey or brownish opacities, exactly mapping out the figure of the sutures of the cortex and situated very superficially. Ordinarily there are other concomitant signs of senescence of the lens, so that this punctuation should be considered as a senile process.

Presenile or senile opacities of the lens take on particular

forms (depending upon the layers affected), which allow us to distinguish types of grey cataract.

The principal ones are :—

Coronary cataract ;
Dilacerated cataract ;
Peripheral cuneiform cataract ;
Dust-like cataract in concentric layers ;
Posterior saucer-shaped cataract ;
Nuclear cataract, with its black variety.

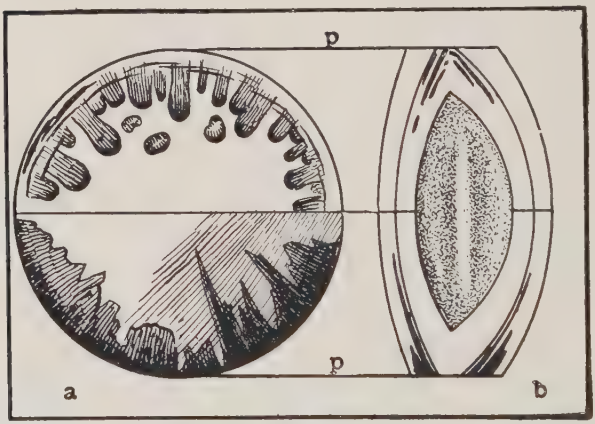

FIG. 37.—Diagram showing the principal types of opacification of the lens. *a* is a frontal view ; *b* an optical section ; *p* marks the border of the dilated pupil. Above, opacities, chiefly club-shaped, of a coronary cataract ; below, senile cuneiform opacities. In *a*, to the right, lamellar separation. In *b*, in the middle, nuclear cataract involving only the fœtal nucleus and leaving free a little central interval.

The characters of each type are gradually effaced in proportion as maturation develops, and the processes described above, lamellar separation, formation of vacuoles, etc., further complicate the clinical picture.

Coronary cataract is *par excellence* a presenile form. *After puberty it is found in 25 per cent. of all persons examined.* It occupies a zone in the form of a crown, corresponding to about three-quarters of the radius of the lens, away from the centre. It affects the outer layers of the nucleus and the deeper layers of the cortex.

The opacities are most often *club-shaped* (*cf.* Fig. 37). The thickened rounded end is turned towards the centre of the lens, and the peripheral end is gradually lost by becoming attenuated. There are also seen nummular or annular opacities, and, towards the periphery of the lens, opaque lines of varying length arranged circularly. *All these opacities are very thin*, so that they often have a blue or yellowish tint, depending upon the method by which they are illuminated. Their thinness allows them to escape notice during ophthalmoscopic examination, if the pupil is not dilated.

These opacities are very stationary and only progress extremely gradually. As they are peripheral, vision remains good for dozens of years. When they are sufficiently numerous, these opacities form a veritable crown.

This coronary type of cataract, as a rule, is combined moreover with other senile changes, such as clefts, radiating opacities, etc. (Vogt, Weissenbach, Horlacher, Gjessing).

To study this cataract it is absolutely necessary to dilate the pupil completely.

Under the name of **dilacerated cataract** Vogt has described a form of opacification probably congenital in origin, related to coronary cataract, as well as stellar cataract. The opacities have a peculiar appearance, like moss. Their edges are combed out and they are pierced with holes. They are confined within very thin layers and may have blue or green reflexes, in direct illumination. They are always situated in the deeper layers of the adult nucleus, but chiefly in the superficial layers of the fœtal nucleus. They show a predilection for the axial parts of the lens.

If the types of opacification we have described above may be styled presenile, the following forms appear chiefly at an advanced age.

It happens that opacities appear sometimes at the equator, in the superficial layers of the nucleus or the deep layers of the cortex (cuneiform cataracts, dust-like cataract in concentric layers), sometimes only in the posterior layers (saucer-shaped cataract and finally sometimes in the nucleus (nuclear cataract).

Cuneiform cataract is composed of opacities occupying concentric layers of the deep cortex, and first of all appearing at the periphery of the lens. The opacities are whitish, dense, and *end in a point towards the centre of the lens* (*cf.* Fig. 37). Their peculiar form, as well as their greater density, distinguishes them from the opacities of coronary cataract. Cuneiform opacities, if they are sufficiently numerous, may, however, assume a crown-shaped distribution. *They are posterior as well as anterior*, the anterior being joined to the posterior at the periphery of the lens.

The fusion of opacities sometimes obliterates their pointed form and gives rise to opaque plaques approximating more to the shape of a segment than that of a sector. This type of opacification may complicate coronary cataract or be combined with clefts, or radial opacities, etc., and very often with lamellar separation.

Dust-like cataract in concentric layers is composed of very small opaque dots, amongst which are sometimes seen larger foci. The layers affected are those of the surface of the adult nucleus and the deepest layers of the cortex. This cataract only appears in elderly people. It may be combined with other forms of opacification, chiefly with coronary cataract.

At its onset this cataract is recognised by the fact that *the anterior band of the adult nucleus, and the posterior, appear thickened and more intense towards the equator*. So as to appreciate the concentric arrangement of the opacities, it is necessary to use a perfectly focussed light.

Posterior saucer-shaped cataract appears in the posterior layers of the cortex. It is important to know exactly how to distinguish this from complicated cataract, which is not always easy.

The opacification is confined to *a single layer of the cortex very near to the posterior capsule.* The opacities are dense, although not very large, and often have a crystalline appearance. Between the opacities rounded holes are seen (vacuoles).

The opacity sometimes increases very gradually, or may be combined with other senile changes or opacification of the nucleus.

This opacity, however, affects the vision very early, and one is sometimes astonished to note a poor visual acuity when the opacities appear slight and may even be overlooked with the ophthalmoscope.

We may note here, too, as a matter of curiosity, true *concentric linear opacities*, situated at the periphery of the lens, in the deep cortex, and which, by fusing with one another, may take on an annular form.

Stanka has observed, in a glass-blower suffering from cataract, a *tiny displacement of the cortical opacities under the influence of accommodation.* Atropine suppresses this movement. It confirms the phenomenon of internal accommodation of the lens recognised by Gullstrand, and noticed also by other observers.

These movements have been seen in the anterior cortex. Later observations have shown that the opacities that are displaced consist of vacuoles running together between the fibres.

Nuclear cataract is gradually produced by an increase in the optical density first of the fœtal nucleus, and then of the adult. It is to be noticed that *the opacities which form the cataract remain extremely small*, unlike those of the cortex (*cf.* Fig. 37*b*).

Nuclear cataract usually ends by becoming complicated with senile opacification of the cortex, and is not rare. The presence of nuclear cataract may be noted when the cortex is relatively clear.

It starts by an increase of the diffusion of light in the deep layers of the fœtal nucleus in the neighbourhood of the central interval, which may, moreover, remain relatively clear for a long time. Then the more external layers of the fœtal nucleus are affected in their turn. At this time the fœtal nucleus is opaque more or less throughout and still separated from the bands of the adult nucleus by a relatively dark space. *The Y-shaped suture now stands out sharply in white.* This dark space becomes narrower little by little, and the time arrives when the whole of the adult nucleus becomes opaque in its turn, the anterior and posterior bands fusing with the internal haze. Most frequently

the cortical layers are more or less affected, and show numerous opacities.

Sometimes an extremely fine haze of the fœtal nucleus extends very gradually towards the periphery and the cortex still remains clear. We then obtain those coloured forms leading gradually to black cataract by passing successively through yellow, red and brown (*cataracta brunescens*).

Under the name of *false lenticonus*, Demicheri has described (*Ann. d'Oc.*, 1895, p. 93) an interesting formation, which among foreigners has the name of the *lens with double focus*, but for which the description **central hyperrefringence** seems to us the more correct.

While the peripheral parts of the lens are emmetropic or hypermetropic, as may be proved by the erect image with the ophthalmoscope, the central parts appear myopic, sometimes to a high degree.

Demicheri thought that the cortex was the cause of this, and that its index was reduced, producing a peripheral hypermetropia. However, hypermetropia was often absent. *The slit-lamp shows that it is chiefly the fœtal nucleus that is altered.*

If patients affected by central hyperrefringence are examined, we note that *the surface of the nucleus is very evident and luminous*, and that within the nucleus the optical density is increased. The index of refraction of the nucleus undergoes a considerable increase. The cortex may still be clear or show the ordinary opacities. It is possible that an increase in the curvature of the nucleus contributes also to the increase of the refringence of the axial parts of the lens, but this hypothesis is unnecessary.

In short, there occur nuclear changes allied to those which cause nuclear cataract and black cataract, in both of which we have often noticed a central hyperrefringence.

At the onset of **black cataract** a differentiation of the adult nucleus, which is limited by very luminous bands, is noticed. The fœtal nucleus shows an increase of optical density as well as a uniform yellow tint, *which appears more intense in the posterior than in the anterior parts.* The Y's stand out sharply in white. The posterior cortex shows a golden yellow tint,

which is sometimes very bright. This coloration is chiefly due to optical reasons, on account of the interposition of the nucleus. At the same time the anterior and posterior cortex only show the usual opacities, corresponding to the age of the patient.

It is remarkable that the anterior cortex may remain quite clear, with its normal bluish tint. In front of the anterior bands of the adult nucleus and of the fœtal nucleus there is seen a relatively dark *interval*, due, possibly, to the effect of contrast. We have seen in some cases a *reduplication of the anterior band of disjunction*, which may possibly be explained by a sclerosis of the epithelium. What is most striking is the poor visual acuity admitted by the patient when, with the ophthalmoscope, the red reflex from the fundus of the eye is scarcely altered. Thus, in a personal observation, the patient hardly counted fingers at 2 metres, yet the papilla and vessels were still visible. When illuminated with a concave mirror, the nucleus stood out a little more distinctly.

TRAUMATIC LESIONS

In **traumatic dislocation of the lens,** if it comes to rest in the anterior chamber, it is easy to examine the lens in its entirety. The zonule may be completely absent or preserved in places. The fibres which remain adherent to the lens undergo a degeneration that increases their opacity and makes them more visible. They may be seen floating in the anterior chamber. Usually there are traces of blood on the lens, principally near the periphery, and on the iris.

In a personal observation on a woman of sixty-eight years, examined two weeks after the injury, no trace of the zonule was to be seen. The lens had remained relatively clear, except for a slight yellowish nuclear opacity, but the sutures gaped a little. The tension was 70 mm. of mercury.

Authors who have examined lenses removed by Barraquer's method have reported an absence of the zonule, a preservation of the capsular third of the zonular fibres, and more rarely the detachment of the retinal insertion with tearing away of cells and pigment.

In **subluxation of the lens,** a hernia of vitreous may be seen to appear at the margin of the pupil, but this is not always the case.

The partially dislocated lens often permits the study of the zonule *in situ*. According to Meesmann, the alterations in the zonule consist in a stretching of the fibres, with loss of their elasticity, in localised thickenings, and in increase of their opacity. A traumatic coloboma of the lens at the spot where the zonule is altered only arises in young subjects.

The same changes may be seen in congenital subluxation of the lens.

A **traumatic rupture of the zonular layer** (of Berger) has been seen sometimes in the living. In an observation of Meesmann it occurred in a man of twenty-eight years examined six months after the injury. The lens was lying down and in behind the iris. No trace of a tear in the capsule was to be seen. The superficial cortical layers were slightly opaque. At the edge of the lens, which was regularly notched, no trace of zonule was visible. On the other hand, near the free border of the iris, the presence of a *fine floating crinkled membrane* was noted, showing a concentric and radial striation, which the author identified with the layer of Berger and which he thought was produced by a thickening of the fibres of the zonule.

Rupture of the zonular layer may also occur among *glass-blowers.*

This was first observed by Elschnig in a subject, fifty-six years of age, who had been a glass-blower since the age of fourteen years. One eye had been operated upon for cataract. On the surface of the cataractous lens of the other eye was seen a fine clear pellicle, the free border of which was slightly rolled forward and whose fixed extremity was gradually lost in the anterior capsule, towards the pole of the lens.

In the second case observed by the same author, the subject, sixty-three years of age, had been a blower for forty years. In the two eyes a fine, clear membrane was seen incompletely separated from the anterior capsule, measuring 3 mm. in one eye and 4 mm. in the other. Both eyes were cataractous.

The third subject was aged fifty-two years, and showed, besides the rupture, opacities of the lens. It was the same in a fourth subject of fifty years of age. The detached layer here had a rectangular form, and the edges were slightly rolled up forwards. In these last two cases, in contradistinction to the two former, the *line of rupture* was clearly seen in the layer which remained adherent to the lens.

The frequency of the rupture of the zonular lamella is given to us in the statistics of Kubik. Among sixty-three glass-blowers examined, it was found three times, and always in one eye. Each time the detached portion was limited by straight lines. In three other cases interesting alterations were found, which were possibly the point at which the rupture started. In one case (of thirty-seven years), there occurred a line in the form of a Y, having a golden glitter with focal illumination. In the second case (of fifty-two years), a very fine brilliant line was seen. In a later case (of forty years), the straight line, of glassy appearance, had a length of 2 mm. All these changes were monolateral.

It is stated that, of the six persons who showed these changes, not one of them used any protection.

These observations of rupture of the zonular lamella in glass-blowers suggest the hypothesis that possibly a similar process occurs when after an injury a change in the capsule is seen without any opacification of the lens, or may we suppose that a deep layer of the capsule has remained intact ?

Vossius, in 1903, described a traumatic cataract of peculiar form which ought rather to be called **traumatic annular deposit.**

This epicapsular deposit is seen in *young individuals who have suffered a contusion of the eye* (tennis ball, etc.).

The deposit has the form of a ring of 2 to 6 mm. diameter and a fraction of a millimetre in width. The diameter of the ring corresponds to that of the pupil at the time of the injury.

Examined by the slit-lamp, the deposit shows itself to be formed of a *great number of brown amorphous granules lying on the capsule.* These granules may be so dense and numerous as to efface the shagreen of the lens beneath them.

The deposit is absorbed very gradually in the course of several weeks, or even several months, and may disappear entirely. It mainly consists of grains of pigment. Vogt has given the reasons which militate in favour of this idea. It may form without there ever having been a hyphæma.

Sometimes, at the onset, there are noticed some very fine opacities really lenticular, situated under the pigmentary deposits. Or, rather, very discrete sub-capsular opacities are seen to appear *after* the resorption of the pigment. It seems that these opacities, the site of which is the anterior band of disjunction, may persist for several years.

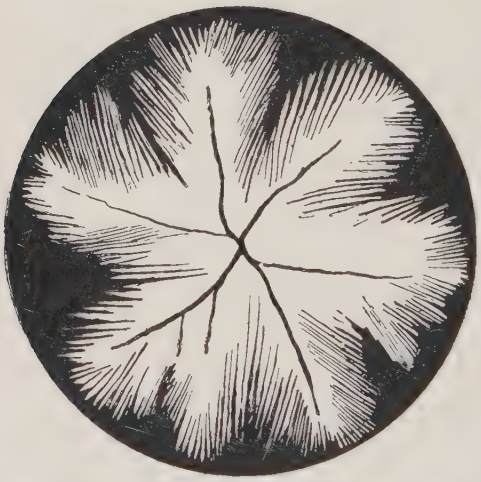

Fig. 38.—Diagram representing the usual form of traumatic posterior cataract. It occurs as a rosette or star, the rays of which are marked by the sutures of the cortex. The design of the lens fibres inserted into the sutures is well seen. The cataract occupies a sub-capsular zone at the posterior pole of the lens.

The most plausible hypothesis for the genesis of the annular deposit is that it is an *impression of the pupillary margin* driven against the capsule by a sudden increase of the intra-ocular pressure. Probably, at the same moment a transudation of fibrin takes place from the vessels, which facilitates the adherence of these pigment granules.

The ring of Vossius then has a perfectly typical appearance and composition, and this name ought not to be applied to the epicapsular deposits following a hæmorrhage, as some authors have.

Folds of the capsule may be observed after certain contusions of the globe. *Folds of the substratum of the shagreen*—that is to

say, of the epithelium and the superficial layers of fibres—are more rare.

Traumatic cataract frequently occurs without any changes in the capsule being revealed by the slit-lamp. It is in this case an *indirect form* of cataract with well-known characters, which allow it to be distinguished easily from the senile and complicated forms.

It occupies the axial subcapsular layers of the cortex and takes the form of a rosette. It is formed of a thin layer sharply delimited from the rest of the cortex. The rosette form is determined by the arrangement of the sutures, *which the opacity renders clearly conspicuous.* Towards the periphery, the cataract is marked off by fine white lines, in parallel groups, more or less radial in their general disposition, which confers upon them a feathery appearance (*cf.* Fig. 38).

The opacity is contained in a thin layer of equal thickness throughout, and usually shows no lustre.

As we know, this type of opacification is susceptible of complete retrogression.

The opacities consist of very fine droplets extending under the capsule and between the lens fibres. According to Vogt, the drops seem to spring more from the fibres themselves than from the neighbouring fluids (vitreous humour or aqueous).

Traumatic cataract may be confused with complicated cataract or with the saucer-shaped senile type. But these two forms have a very bright lustre and are not affected by the design of the fibres. Note must also be made of the presence of other signs of contusion, lesions of the iris, liberation of pigment in the vitreous, etc.

Electric cataract, examined by the slit-lamp, seems to be related morphologically with the traumatic form, although the published descriptions may be rather different.

Koeppe saw in a man of twenty-five years, three months after an accident by short-circuit, bullous protuberances of the epithelium or of the capsule. The anterior cortex was a little hazy. The impression given was that the cortex was separated

from the nucleus by a collection of fluid, which ultimately disappeared. The opacities showed a bright lustre. The visual acuity of the injured man is not stated.

The same author saw, in other cases, opacities of the posterior layers taking the form of a rosette and following the sutures. He noticed also a bright lustre. There were no vacuoles. In one case the visual acuity was 5/35. The examination was made one month after a lightning stroke.

In Koeppe's observations, there were no symptoms of irido-cyclitis.

Freese examined a woman of forty-eight years, four months after electrocution. He found anterior sub-capsular opacities, ocupying in one eye the supero-internal quadrant and having the form of a star in the other. They were composed of round or oval vacuoles, situated exactly under the capsule, and of very fine opacities in connection with the sutures. The nucleus and posterior layers were intact.

This author has seen appear, in several cases in rabbits which had been submitted to various forms of electric discharge, slightly marked opacities, situated in the anterior superficial layers of the lens and later vacuoles raising the capsule.

Gjessing, in the two eyes of a boy of twelve, who had suffered an electric shock (50,000 volts), saw opacities appear, but only several months after the accident, which he describes as follows: Left eye: anterior sub-capsular layer slightly hazy, of spongy appearance, containing a multitude of filiform opacities of all calibres, white, and passing in all directions. Among them, fine round or polygonal opacities, and in places, vacuoles. Vision of the left eye: counts fingers at 5 metres. Right eye: little vacuoles of different sizes, which Gjessing localises, probably wrongly, in the capsule, which is affected as well as the layer immediately subjacent. The opacity consists of fine lines running in all directions and not mapping out the design of the fibres. Among these lines are some fine brilliant dots. In the deeper layers, which are otherwise transparent, there are opacities of different size, in the form of a corkscrew. The adult nucleus seems intact. There

are some irregular spots in the posterior layers. Vision of the right eye, 5/12.

In an observation by Viterbi, the opacification had already begun a few days after the injury and had mapped out the sutures and the lens fibres.

The older authors (Hess, Kiribuchi, etc.) had already noted subcapsular and cortical opacities, sometimes in front only, sometimes behind or in both situations.

In **traumatic cataract with opening,** and more or less complete destruction **of the capsular sac,** masses of lens substance show a snowlike brightness with the slit-lamp. Bundles of fibres are seen which, by becoming broken up, separate more or less from one another. If one part of the lens is not affected there are seen, in an intermediate zone between the unaffected part and the opaque bundles, alterations like those of indirect traumatic cataract described above: fine droplets apparently situated between the fibres and mapping them out.

The cataract of siderosis gives interesting appearances. The bands of discontinuity are more or less effaced and have a characteristic yellow tint. This yellow coloration is especially well marked in the anterior band of the lens. The anterior shagreen is also yellowish. The whole of the anterior surface of the lens appears covered with a *multitude of small brownish dots*, which are grouped in such a way as to maintain between them unbroken twisted canals. According to Vogt, each brownish dot measures about 20 microns, which corresponds to the size of the cells of the lens epithelium. In point of fact, these dots, found *directly under the capsule*, are none other than the epithelial cells themselves.

Toward the periphery, much grosser collections of rust are seen caused by the fusion of brown dots and forming a ring.

In siderosis bulbi changes in the cornea (*vide supra*) and in the vitreous (*vide infra*) are seen.

We remember, for differential diagnosis, the subcapsular situation of very fine opacities, their rusty colour, the yellow colour of the anterior band, the gross brown collections, the

coloration of the section of the cornea, the absence of the design of the fibres, and of the lustre, and finally the history.

O. Purtscher has described the characters of a **cataract due to the presence of copper** in the interior of the eye, or at least of an alloy of copper. The lens opacity which arises is characteristic, although not observable by the usual methods of examination, the marked examples excepted.

Fig. 39.—Cataract, in the form of a sunflower, due to the presence of a particle of copper within the eye. The area corresponding to the pupil in miosis remains free. The rays of opacity correspond to the ridges on the posterior surface of the iris. Some dark vacuoles are seen.

There occurs an *extremely shallow opacity, situated in a layer directly subjacent to the anterior capsule, grey-blue or grey-green in colour, taking the form of a sunflower.*

The anterior axial parts of the lens remain relatively unaffected. This less-affected part is contained within a ring which exhibits the maximum of opacification and from which a certain number of slender opacities radiate towards the periphery (*cf.* Fig. 39).

The opacity shows an extremely bright polychromatic lustre. (This sign may be visible sometimes to the naked eye by oblique illumination.) No portion of the design of the sutures or fibres is seen. The rest of the lens is quite normal.

Seen by high magnification, the opacity is shown to be composed of minute dots, which extend over the whole lens, and which, by localised condensation, take on the form of a sunflower. Jess attributes the bright lustre of the copper cataract to the presence of a thin layer of copper which he has

found beneath the anterior capsule in histological examination. Yet the lustre is also pronounced at the posterior pole of the lens, where copper has not been recovered. Vogt thinks that the lens epithelium is also impregnated.

It is very probable, as the researches of Lindberg on naphthalin cataract lead him to suppose, and as the deductions of Vogt establish, that *the condensation of opacities is facilitated by the rubbing of the posterior ridges of the iris on the lens.*

The ring corresponds to the border of the iris in miosis, the average width of which is about 2 mm.

A very attentive examination reveals, in the opaque areas, the presence of rounded holes apparently unaffected (vacuoles ?).

Copper cataract is accompanied by vitreous opacities (*vide infra*).

From the point of view of differential diagnosis, it is necessary to remember the situation of the opacities, anterior and immediately beneath the capsule, the bright-coloured lustre, the sunflower shape, the absence of the design of the fibres and the sutures.

Secondary cataract shows very different aspects, according to the age of the subject, the operations practised, etc. Its elements are :—

(*a*) Remains of the capsule, especially the posterior.

(*b*) Unabsorbed remains of the lens fibres.

(*c*) Proliferation of the epithelial cells of the lens having either an amorphous appearance (lens cushion of Soemmering) or a peculiar globular form (cells of Elschnig).

(*d*) Pigment, more or less abundant, which, as an observation of Brückner shows, may, in certain cases, proliferate in a remarkable way.

(*e*) Exceptionally inflammatory cells and fibrin, and sometimes strands of vitreous included in a pseudo-membrane.

When the lens has been extracted in its capsule, the strands of the anterior layers of the vitreous, which always form a hernia forwards, seem to undergo a true opacification.

The capsule almost always exhibits folds, more or less numerous and crowded together. Often one recognises the

arrangement in pairs of reflexes caused by foldings. A polychromatic lustre is usually visible on more or less wide areas of the secondary cataract. Folds of the capsule are often seen to converge towards an adhesion of the iris. These folds must be considered as *fixed*, and mydriatics, for example, do not modify them appreciably.

Remains of lens fibres will be recognised by their snowy colour, their arrangement in bundles and their finely frayed appearance. It is not rare to encounter such relics of fibres, especially in children, persisting for many years, chiefly in the lower parts of the pupil.

We speak of the *lens cushion of Soemmering* when the whitish amorphous proliferations occupy chiefly an equatorial zone.

The *globular cells of Elschnig* give a very curious appearance with the slit-lamp. Each cell is rounded, sometimes perfectly round, sometimes a little elongated, always transparent. Illuminated by a beam of light, the cell presents two little luminous reflexes, very bright, and due, one to the anterior convexity of the cell, and one to the posterior concavity, which is displaced in the opposite direction to that of the light when it is viewed laterally. The globular cells are usually multiple, like a bunch of grapes, and may well be compared to frog spawn.

The bunches seem to us often to arise from an iris synechia.

In a personal observation three years after the last discission, in a little girl of ten years, we have seen globular cells again increase considerably in the space of some months, the large ones taking on a pendulous form. The mass of cells filled at this moment one-half of the pupil, the largest cell having a diameter of 1·5 mm. Spontaneously, the whole collection suddenly became detached and disappeared behind the iris. At the same time, the patient noticed an improvement of the visual acuity.

We note that after a contusion Vogt has reported in one subject the formation, in the interior of the lens, of elongated cells resembling the cells of Elschnig and starting at the equator.

Vogt has succeeded in causing in a rabbit the formation of a

cataract by the application of infra-red rays of a wavelength of 670 to 700 millimicrons. The rays, produced by an arc lamp of high amperage, are filtered and cooled by two cuves in which circulate respectively water and a solution of iodine in iodide of potassium. A single application of less than an hour suffices to produce a cataract *involving the cortex only*, both anterior and posterior, with vacuoles.

Ultimately the new-formed layers separate the opaque layers from the capsule and drive them into the depths of the lens.

Heat rays, to which *ironfounders* are exposed, seem often to produce a typical cataract which Schnyder (personal communication) has found four times in thirty-one workers : a *sharply demarcated* posterior polar cataract in opaque layers *reaching the periphery* (optical section) and accompanied by *alterations of the anterior capsule* similar to those of glass-blowers.

Post-traumatic lens atrophy remains completely hidden to the ordinary means of investigation. The slit-lamp often reveals modifications in the external form and internal structure of the lens.

Some months or some years after a serious contusion of the globe one may observe in the optical section that the lens is considerably flattened. *The sagittal diameter may lose a quarter or even a third of its value.* The relations of the bands (surfaces of discontinuity) may be altered and their peripheral divergence diminished. This diminution always indicates that a marked atrophy has taken place.

It appears that the layer of fibres, which is subcapsular or at least *subepithelial* at the moment of the contusion, may become opaque *subsequently*. Vogt reports several cases where he has seen, several years after the contusion, sometimes a *cataract in the form of a rosette* in a *thin layer* in the anterior part of the cortex, sometimes a complete *zonular cataract*. The distance of the opaque layer from the capsule allows a calculation as to the date of the injury, as also does its relation to the bands which are preserved. However, the addition of new fibres may have been retarded and altered by the accident.

These phenomena ought, then, to be studied the more closely, considering their great importance from the medico-legal point of view.

If the capsule has not been injured by the traumatism, the lens changes are usually symmetrical. It may, however, be otherwise. We have seen, after a severe contusion of the globe, the upper part of the lens flattened considerably to such an extent that the posterior band actually appeared in its upper half, slightly convex forwards.

PATHOLOGICAL CHANGES

Pathological changes of the lens, an avascular organ, express themselves by opacities of its substance. It will be necessary to treat of complicated cataract, *in the strict sense*, that is to say, the cataract produced by inflammation of neighbouring membranes, and the opacification which accompanies certain general diseases : myotonia atrophica, diabetes, etc.

Complicated cataract presents to the slit-lamp characters so marked that an experienced eye is able to recognise it and distinguish it from all other types of opacity.

The onset is manifested by a *marked polychromatic lustre of the posterior band of the lens*. This phenomenon is chiefly marked towards the posterior pole of the lens—that is to say, in the middle of the posterior band, if the beam is well centred on the lens. We have seen above that it is at this spot that the zone of specular reflection is found. In the normal state the zone of specular reflection presents a whitish sheen with slight lustre, but, with the onset of complicated cataract, an iridescence adds to it several colours grouped in areas, one by the side of the other, like those on a geographical map.

At a more advanced stage, we recognise that the iridescence is produced by the presence of faint, flaky opacities situated near to the posterior pole of the lens and immediately under the capsule.

These opacities gradually take the form of a rosette. If they are sufficiently dense, if their surface is *tufted*, or characteristically *breadcrumb-like*, the polychromatic lustre is obliterated,

and only remains visible at the periphery of the rosette. At this time there are usually seen some crystals of cholesterin or little vacuoles shining here and there.

Later the opacities multiply more and extend in two directions: *towards the centre of the lens, and towards its periphery.* Sometimes the spread of the opacities in a sagittal direction is not continuous, but takes place by leaps. Also there frequently appears, directly behind the posterior band of the adult nucleus, a new centre of opacification whence the affection spreads towards the periphery. *This opacification by stages is pathognomomic* of complicated cataract.

At this stage the anterior pole of the lens also shows a polychromatic lustre, then opacities which multiply like those at the posterior face.

In becoming larger and denser, the posterior opacities take on more and more a yellowish tint. But it is always characteristic of these opacities that they are never marked off sharply from clear layers and remain submerged in a cloudy haze.

Such are the characters of complicated cataract, put forward in such a masterly way by Vogt, and which enable it to be distinguished from senile or traumatic cataract. We may add that the slit-lamp allows us to make a diagnosis at a time when the ophthalmoscope discloses absolutely nothing.

Complicated cataract may be confused, on the one hand, with senile saucer-shaped cataract, and, on the other, with traumatic cataract.

In saucer-shaped cataract there are usually concomitant senile opacities in the cortex at the equator. Its form is dome-shaped and not like a rosette, its thickness is uniform throughout and not increased in the axial parts, as is the case in complicated cataract. Further, the opacities which constitute saucer-shaped cataract are never enveloped in a cloudy haze, which is met constantly in the complicated form.

As to traumatic cataract, it is recognised chiefly by the design of the fibres which it constantly accentuates, by the fact that it may be partially or completely absorbed and by the habitual absence of the polychromatic lustre.

It is hardly necessary to say that in an aged person complicated cataract may be combined with various senile opacities and alterations.

We may also add that *heterochromic cataract* is also of the complicated type.

Several authors have observed cataract in **myotonia atrophica** (*dystrophia myotonica, syndrome of Steinert*), but the characters of the opacification of the lens have only been differentiated in the past few years. These characters are, moreover, so clear that they have led Vogt and Lüssi to suspect the general disease upon a single examination of the lens.

It is known that myotonia atrophica, although hereditary, is not congenital, but starts between the ages of twenty and thirty years. The cataract is the more striking in that the patients never reach a great age. The first symptom is a certain stiffness of the fingers, which are relaxed only with difficulty. Then follows atrophy, which extends over the various muscles of the arm, neck, face and leg. The *facies myopathica* establishes itself. The speech becomes thick. There is also noticed baldness, atrophy of the testicles, or premature menopause, nervous and psychic changes, etc.

This cataract is formed of a multitude of *small angular opacities situated in the superficial layers of the cortex, anterior as well as posterior*. The space between the capsule and the band of disjunction, however, remains free, as also the nucleus. The opacities form a stippled and speckled design in which numerous coloured dots, usually red and green, may be seen sparkling (cholesterin ?). Sometimes their arrangement takes the form of a star, as was the case in a patient of Lüssi ; at other times the cortex is uniformly affected, as in the observations of Vogt.

In **post-operative tetany** opacities of the lens may be seen some years after the thyroidectomy. The opacities are of three kinds : *flaky, powdery, crystalline*. The flaky and the crystalline occupy only the space between the band of disjunction and the surface of the adult nucleus. The powdery opacities extend more deeply, to the central interval. In two of three

cases observed by Knüsel, *the lens was appreciably flattened.* According to a personal observation, it appears that it takes at least a year for the opacities to develop. Crystalline opacities showing a red and green lustre especially are also found in myotonia atrophica, and we have seen them in a case of Mongolian idiocy. This fact is worthy of note. There is possibly some disturbance of internal secretions at the bottom of these three diseases.

All forms of cataract have been seen in **diabetes.**

Now, it seems that one kind of cataract, rare to be sure, is peculiar to this disease. Schnyder (Soleure), examining fifty-nine diabetics (twenty-eight men and thirty-one women), only finds it in one woman of thirty-three years, whose corrected vision is 6/36. The patient eliminated 100 to 150 grams of glucose daily, and after two weeks of dieting the blood still contained 0·272 per cent. of sugar.

The two lenses were not thicker than usual, and seemed, if anything, thinner.

The cataract was formed of a *multitude of small cloudy opacities situated immediately beneath the epithelium,* becoming gradually lost in the deeper layers. The opacities were grouped into areas of 0·04 to 0·10 mm. in size, and had in places the appearance of droplets. Small coloured corpuscles were also seen to glitter. At the posterior face there was also a layer of opacities, which did not show the axial distribution of a complicated cataract. The lustre of the anterior and posterior bands was slightly marked. *In places, numerous clear clefts separated the fibres,* which were particularly well seen on the anterior face of the lens.

CHAPTER IX

THE VITREOUS BODY

SPECIAL TECHNIQUE

Only the axial parts belonging to the anterior quarter or third of the vitreous are accessible. A deeper examination necessitates dilatation of the pupil with homatropine and cocaine. In young people, part of the vitreous is visible without dilatation of the pupil. Cocaine alone may be helpful, but under the beam the pupil contracts so much as to counteract the cocaine mydriasis. With old people, however, (in whom one would hesitate to instil mydriatics) cocaine suffices, if at least half an hour is allowed to elapse after repeated instillation before beginning the examination.

The angle of *incidence* of the beam should be about 30°. It is well, also, to project the light *from the nasal side* as well as from the temporal. In this way a much greater field may be explored. The examination is begun from the temporal side of the patient, who looks straight in front of him.

The *dark adaptation of the observer's eye* is important. It would be useless, however, to wait more than five minutes. Baffling reflexes should be carefully avoided. If a Koeppe's tube is not used, the illuminating lens should be surrounded by a piece of black cardboard, or better, *two* cardboard diaphragms should be placed on the arm of the lamp. The room where the examination is conducted should be almost, if not absolutely dark.

The *slit* should be of *medium width*, the narrow beam finding little application here, as it cuts down the intensity of the light too much. It will always be used to determine whether a change belongs to the posterior capsule or to the vitreous, and the depth in the vitreous of the point under observation.

The *arc lamp* gives excellent results here, especially if the media are slightly hazy. It allows of a further narrowing of the beam while maintaining a sufficiently intense illumination. It is essential for observing the details of the structure of the vitreous.

A *magnification* of 23 diameters (oc. 2, obj. *a* 2) will usually suffice. It will always be used in the preliminary examination, while oc. 4 and obj. *a* 3, giving a magnification of 61 diameters, may be used later. Oculars 5 and 6 are hardly suitable for the living subject. If obj. *a* 3 is used, care must be taken not to bring it into contact with the patient's cornea! This could only happen in an examination of the vitreous by an unskilled observer. It can be avoided by a very simple manœuvre. Before putting his eyes to the oculars the observer will bring the microscope right up to the cornea, then focus by withdrawing it from the globe.

The investigation usually begins with the focussing of the beam on the posterior surface of the lens. Then the posterior band of the lens, easily recognisable by the characteristic lustre of the central parts, is sought with the microscope. If the right eye is being examined, for example, the lamp being on the right of the patient, the observer will move the beam outwards with his left hand, while moving the microscope gently up with the right. The object of this manœuvre is to avoid the zone of specular reflection, which interferes with the examination of the structures behind it.

THE NORMAL VITREOUS

Orientation.—The *posterior band,* produced by diffuse reflection of the light at the posterior surface of the lens, marks the anterior limit of the vitreous. The posterior fœtal sutures form an inverted **Y** (⅄) situated more or less near to the posterior capsule and providing an excellent *point de repère.* The sagittal projection from the centre of this ⅄ on the capsule may be taken as marking exactly the posterior pole of the lens.

On focussing the beam and the microscope on the posterior capsule, and moving them little by little towards the nose, we always find two curious vestiges : an *arcuate line*, described by Vogt, and a small, more or less rounded opacity, to which the *vestige of the hyaloid artery* is attached.

The insertion of the artery is situated 1·5 to 2 mm. to the nasal side of the posterior pole of the lens. It is marked by a **hyaloid corpuscle** varying in shape and size, but always whitish in colour. The vestige of the artery is a whitish cord, some-

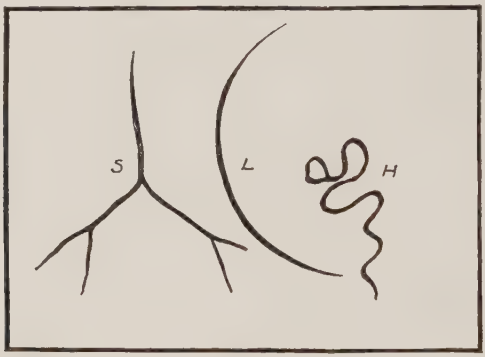

Fig. 40.—Diagram showing the relation of the posterior ⅄ of the fœtal nucleus (*S*), of the arcuate line (*L*) of the insertion of the remains of the hyaloid artery (*H*) in a right eye. The artery is found on the nasal side, separated from the posterior pole of the lens by the arcuate line, the concavity of which is turned towards the artery.

times several millimetres in length, the end of which floats freely in the vitreous. *This cord is constantly twisted like a corkscrew* and exhibits a certain mobility with the movements of the eye. But in the resting eye, the spiral form can be made out. More rarely, a part of the cord, or all of it, is fixed to the posterior lens capsule. The attached part then shows a series of bends lying in the same plane. When the whole remnant of the artery is attached to the capsule it is found below the posterior pole.

The **arcuate line** is a thin whitish crescentic figure, sometimes clearly visible, at others scarcely perceptible. It is situated *between the posterior pole of the lens and the insertion*

of the artery, with its concavity turned towards this structure (*cf.* Fig. 40).

Vogt suggests that this line marks the line of reflection of Cloquet's canal.

In order to see the line and the artery, the beam should be exactly focussed. A curious phenomenon of illumination may lead to an error. It happens that the corneal reflex lights a part of the mount of the objectives, and this is reflected in the cornea in such a way that a semilunar image is formed in the deeper parts of the lens. This image so closely resembles the arcuate line that it may be mistaken for it. These catoptric images are recognised from the fact that when the beam is moved slightly, *two* exactly similar images of the two objectives are seen, and that in the middle of each there is a luminous point arising from the reflection of the light at the surface of the objectives themselves.

The arcuate line and the remnant of the artery are only visible *outside the zone of specular reflection*. If this fell on them it would efface them completely. It will be necessary then to modify the incidence of the light or to make the patient look a little to the side. If he look to the left, for instance, the zone travels towards the right, and that is due not to the fact of the concavity of the posterior surface of the lens, as has been suggested, but to the situation of this surface in front of the centre of rotation of the globe, like all the other reflecting surfaces of the eye.

Behind the capsule is a shallow space which is optically empty : **the retro-lental space.** The feebler the illumination the deeper this space appears. With the arc lamp, the fibrous framework of the vitreous appears to be closer to the lens.

The **framework of the vitreous** is extremely polymorphous ; with Koeppe, it is possible to distinguish several types which are not clearly defined and between which all intermediate states exist. In the same eye, the appearance may differ with the part examined and with the incidence of the light.

The framework of the vitreous is more or less luminous. An objective classification is naturally impossible. We give, for

teaching purposes, the following grouping by Veragut, who has examined eighty-two children with the Nitra lamp :—

Very luminous framework, 6 per cent.
Fairly luminous framework, 44 per cent.
Slightly luminous framework, 50 per cent.

When the patient has a large coloboma of the iris allowing the peripheral anterior parts of the vitreous to be examined, one has the impression that in this region the fibrous framework is much denser than towards the sagittal axis of the eye. But it is possible that this appearance may be entirely due to the concentric arrangement of pseudo-membranes, which are seen under a different angle at the periphery.

Even with the naked eye one sees, limiting the retro-lental space posteriorly, a more or less vertical reflex which marks the anterior *limiting layer* of the framework of the vitreous. No true structureless membrane exists in this situation, but in certain cases, especially in hernias of the vitreous in an aphakic eye, the luminous reflex is so clear at the surface that one is tempted to admit, wrongly perhaps, a superficial condensation of the fibrils, or a difference between the indices of refraction of the vitreous with its connective tissue and the aqueous humour.

At the periphery of the retro-lental space and sometimes even at its centre, there are often seen filiform structures of unequal thickness more or less entangled and anastomosed, which, in company with Koeppe and Vogt, we regard as **vestiges of the vasa hyaloidea propria** of Schultze. These filaments are more or less distinguished from the vitreous framework by their whiter, denser appearance and often by their twisted and curled forms. They are not inserted at the posterior lens capsule and they are differentiated from the remnants of the hyaloid artery, the calibre of which is more regular and which always have the same position at least at their fixed end.

If we move the beam over the anterior surface of the framework of the vitreous, we frequently note the presence of light horizontal bands, more or less parallel, alternating with dark bands. These may be explained as illuminated folds of a

pseudo-membrane, the dark bands being the less illuminated parts. Sometimes there is a suggestion of genuine *connecting bundles* (*vide* Fig. 41), most frequently vertical in direction. It is rarely that the vitreous is so poor in connective tissue as to show only a few slightly luminous and delicate striæ. We generally see (beginning the examination with the naked eye !) several more or less parallel bands belonging to pseudo-membranes situated frontally. If the wealth of connective tissue varies considerably from one individual to another, it is always identical in the two eyes of the same individual. The more powerful the illumination, the more clearly is the fibrous structure revealed. The strands are far from being always rectilinear. The absolute straightness of the bundles is not then an essential feature of the normal vitreous. But a stable pattern characterises it, as well as a certain consistency recognisable from the fact that movements of the globe do not appreciably alter the pattern, or at least only momentarily.

FIG. 41.—The normal vitreous body of a subject of twenty years, the light coming from the left. On the left is seen the posterior band of the lens where the zone of specular reflection has been avoided. On its right the vertical bundles of the vitreous and a second system of bundles chiefly horizontal and finer. Magnification about × 30. Figure slightly schematic.

In movements of the globe, the whole framework oscillates in a characteristic manner, each point executing a pendulum-like movement.

Well-marked strands or pseudo-membranes in regular mesh belong especially to youth, and are seen chiefly in emmetropes and hypermetropes.

Tiny opacities situated particularly at the intersection of fibrous strands should be regarded as congenital. Usually they are white, like porcelain.

The interfascicular spaces contain a perfectly transparent fluid in the normal state.

Histologists complain that the fibres of the vitreous are too thin to be seen with the magnifications in use. It is possible. We never see isolated fibres perhaps, but only bundles of fibres. But we may perhaps be allowed to point out that what histologists see in their preparations bears only a distant resemblance to the living tissues of the vitreous !

CONGENITAL ANOMALIES

Congenital anomalies of the vitreous are produced by incomplete subinvolution of the hyaloid artery or of the vasa hyaloidea propria.

The persistence of a *relic of the hyaloid artery* fixed to the lens is so frequent that it may be regarded as normal.

We see more rarely *stellate figures*, which seem to adhere to the posterior surface of the lens. Such forms may possess as many as a dozen straight, slender rays. Their appearance is very different from that of the *arcuate line* of Vogt.

Cases of *persistent hyaloid artery* reaching to the papilla are rare. The artery may then be a cord stretching from the lens to the papilla, or the main trunk may, before reaching the lens, divide into a number of filaments which appear to be attached to its peripheral parts.

In a personal observation, a subject with the hyaloid artery visible with the ophthalmoscope, showed a reduction of vision to 6/18. With the microscope one saw no relics at the posterior surface of the lens nor any framework in the interior of the vitreous, where the retro-lental space seemed very deep. But, with the plane mirror and a high + lens, it was observed that the anterior end of the artery was divided into a large number of filaments radiating towards the periphery of the lens, below and laterally.

Relics of the hyaloid vessels proper in the anterior layers of the vitreous may be more or less abundant. They are quite easily distinguished from the connective structure.

SENILE MODIFICATIONS

With age the meshes of the fibrous tissue lose their regularity. The strands are less easily distinguishable, becoming irregular and broken up.

One special change, which we have called **senile "peppering,"** is not constant but is very characteristic. It takes the form of *minute white irregularities on the broken strands*, giving them an appearance of having been sprinkled with fine sugar. They appear to be formed also on the vestigial vessels, which are less easily differentiated from the fibrous strands than in youth.

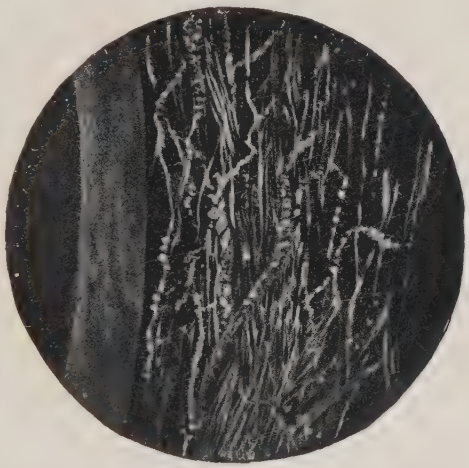

FIG. 42.—The senile vitreous body of a subject of seventy years, illuminated from the left. To the right of the posterior band are seen vascular remains in the form of rounded filaments and broken up bundles of the vitreous. Magnification about × 30. Figure slightly schematic.

In a personal observation, a patient exhibited a senile cataract in one eye. Its fellow was still transparent enough to allow of an examination of the vitreous which showed marked senile peppering. When a preliminary iridectomy was performed on the cataractous eye, loss of vitreous occurred, testifying to the abnormally fluid state of the vitreous (*cf.* Fig. 42).

Nevertheless senile degeneration of the vitreous and that of the lens would not appear to be correlated, and peppering of the vitreous is not always present.

Synchysis scintillans will not be regarded as a result of normal senile changes. We shall refer to it again later.

TRAUMATIC LESIONS

Foreign bodies will only be seen in the vitreous if they are situated in the anterior and axial parts, unless their density is very different from that of the medium. Sometimes, as in an observation by Gallemaerts, the bringing into action of an electro-magnet will enable a foreign body to be discovered and localised, showing it up by the traction it exerts on the framework. The foreign body passing through the lens may also carry with it into the vitreous fragments of lens substance which remain suspended on the framework.

An important sign of **perforation of the coats of the eye** is given by the presence of opacities more or less parallel and *running towards the scar of the perforation.*

Hernia of the vitreous into the anterior chamber may be seen after a wound involving the suspensory ligament of the lens, or after needling of a secondary cataract. In the latter case it is so frequent that it is the rule. The prolapsed portion appears as a gelatinous mass containing a fine irregular fibrillary tissue and brown pigment granules. The anterior limit is clear and marked by a light reflex which is so intense as to suggest a difference in refractive index between the vitreous (humour with fibrils) and the aqueous humour.

The gelatinous mass shows a slight tremor with movements of the globe. Pigment granules are always present. The hernia is liable to shrink in volume, but complete absorption is very rare. One must be careful not to take the prolapsed vitreous for a fibrinous network and *vice versâ.*

We have frequently been able to satisfy ourselves that, with movements of the pupil, the hernia undergoes appreciable displacements in the sagittal direction.

Certain authors (Weill, etc.), have considered that glaucoma following the needling of secondary cataract is due to invasion of the anterior chamber by vitreous. A relation of cause and

effect is not proved. After needling there is always a more or less prominent prolapse, but glaucoma occurs only in a certain number of cases.

An American author has suggested that hernia of the vitreous favours retinal detachment. Nothing is less proved.

Hyphæma of the posterior chamber may be seen in part with the slit-lamp. Illuminated by the beam, it is bright red in colour. It occupies the lower part of the posterior chamber, and is limited above either by a horizontal line, as in a case described by Mans, or by a more or less sinuous line.

One may often see, preferably with the plane mirror and a high + lens, that the blood does not extend to the margin of the lens, but that there remains a space free from blood through which light is reflected from the fundus. When the patient leans the head sideways, a corresponding displacement of the blood may be seen.

In a patient of Ascher's the hyphæma was circular. In a case of Wirth's it was semilunar.

Deposits of blood on the capsule may occur after various injuries. They assume different forms and are reabsorbed very slowly.

In all traumatic lesions of the posterior segment of the eye more or less small **opacities** are seen in the vitreous humour. A simple contusion of the globe, with no other visible lesion, frequently sets free pigment which persists in the form of reddish opacities for several months. But a slight hæmorrhage of traumatic origin produces small whitish flakes which are absorbed fairly rapidly and more or less completely. A massive hæmorrhage causes sometimes red deposits on the posterior lens capsule, which are only very slowly absorbed, much more slowly than opacities in the interior of the vitreous.

Among post-traumatic conditions must be cited the changes due to the presence of foreign bodies containing iron or copper.

In a case of **siderosis of the globe,** Vogt notes, in addition to the destruction of the framework of the vitreous, two kinds of opacities : small, red, punctate opacities having at the most an apparent diameter of 0·05 mm., and white opacities of vary-

ing size, the largest of which take the form of brilliant discs and to which are affixed some of the small red opacities first mentioned.

The same author describes the following changes in the case of an **intraocular foreign body containing copper.** The framework is composed of bundles and pseudo-membranes of a grey-green appearance. In some places the meshes are full of a fine dust of the same colour, while in others they appear absolutely empty. In another case points having a red metallic lustre are also seen. In a third the opacities are partly red and partly white.

PATHOLOGICAL CHANGES

Pathological conditions of the vitreous manifest themselves essentially by two signs :—

(*a*) *More or less complete destruction* of the regular fibrous *framework* of the vitreous ;

(*b*) The *appearance of opacities*, at first very fine, which are precipitated on the fibres (*deposits*, *incrustations*), or seem to float in the spaces (*opacities*, properly so-called).

Flaky, filamentary and pseudo-membranous opacities always indicate a serious alteration in the fibrous framework unless there are recent hæmorrhages. *Stippling*, **vitreous dust** (*état jumenteux* of earlier authors), visible with the plane mirror and + 10 or + 8 D lens, and which has the effect of veiling the fundus and of causing the papilla to appear reddish (pseudo-neuritis), is composed of finer opacities. But with the microscope one often sees very fine or few opacities which remain quite invisible by other means of investigation.

In destruction of the framework of the vitreous, the arrangement of the bundles becomes less regular, their mobility increases, their oscillations with the movements of the eye are no longer simply pendulum-like. The free spaces are increased in size in places. The fibres become unequal in calibre and nodulated. In severe cases, they give the impression of tangled skeins of wool (retinal detachments, etc.). Local agglomerations of fibres alternate with regions of rarefaction, and it is just these irregular

bundles which one sees with the ophthalmoscope and which one takes for exogenous opacities.

Microscopic opacities vary greatly in appearance. Their colour is judged better with low magnifications than with high. The greater the magnification the more is the pure colour diluted and the more there appear colours due to aberrations in the optical system, diffraction, etc.

Sometimes, when the vitreous is so full of blood that focal illumination shows a bright red colour to the naked eye, one is astonished to find under the microscope rather whitish opacities.

The light reflected by the concave mirror of the fundus of the eye, coloured red by the choroidal blood, and illuminating a vitreous opacity situated at the catoptric focus, may also give to it a reddish tint.

Uveal or retinal pigment frequently colours the opacities, giving them a tint varying from yellow to brown. Hæmoglobin derivatives may also play a part which it is impossible to define precisely.

We meet more rarely crystals producing *iridescence* chiefly red and green, and which we attribute to cholesterin, perhaps gratuitously.

The distinction between opacities and deposits naturally remains theoretical. Often an opacity which appears free at the first glance proves to be attached to one or more connecting fibres.

Opacities may also be *precipitated on the posterior lens capsule.* But this is not always the case. Sometimes they are so numerous as to form regular *tracks* on it. This is the case, for example, in traumatic or other hæmorrhages into the interior of the vitreous. The deposits are then of a reddish colour.

Deposits on the capsule have been compared to precipitates on Descemet's membrane. But the conditions are very different, and this view remains theoretical.

Irido-cyclitis. With a feeble illumination, opacities of the vitreous, which are constantly met with in this disease, offer nothing peculiar. The arc lamp, however, shows up a characteristic pointed out by Vogt. They are whitish and assume a

stellate form. This appearance arises from the fact that the altered framework forms fine long prolongations round each opacity.

In **heterochromia of the iris** (pathological and not congenital heterochromia) we find atrophic changes in the iris, nonpigmented precipitates on Descemet's membrane and, in the vitreous, *particularly dense*, faintly coloured *opacities* (Koby), sometimes disc-like in form.

All forms of **chorio-retinitis** are associated with fine vitreous opacities, whitish or coloured. In the acute forms the opacities are more often white. It is probably only later that retinal or uveal pigment is liberated. Thus, in **retinitis pigmentosa** the opacities are at first quite white, which, if one takes account of the presence of pre-retinal folds (Vogt), testifies to the inflammatory nature of this condition.

Sympathetic ophthalmia.—The presence of fine opacities is an invaluable premonitory sign of sympathetic ophthalmia. It even seems as a rule that it precedes precipitates on the posterior surface of the cornea and failure of the accommodation. The opacities are very fine, white or reddish, and are *situated especially in the lower parts of the vitreous.* They may undergo absorption.

Vogt has reported spontaneous recovery in two cases of sympathetic ophthalmia which manifested itself by discrete precipitates and fine opacities in the vitreous.

Recurrent hæmorrhages produce interesting appearances. A localised pre-retinal hæmorrhage, at least at first, may not produce any change in that part of the vitreous which can be seen with the microscope. In massive hæmorrhages there is almost always a *large number of red blood corpuscles adhering to the posterior lenscapsule*, especially on the lower parts, where they form curved bands. These hæmorrhagic tracks on the capsule only undergo slight absorption. In a personal observation on a case of vitreous hæmorrhage in a woman of fifty, the deposits on the lens capsule were not appreciably changed two years afterwards, although the vitreous, at first opaque, had cleared considerably.

At the onset, the vitreous is sprinkled with *whitish* opacities. After a few days very white, delicate, snow-like deposits are formed on the fine fibrils of the framework of the vitreous and also on the vascular remains. Some weeks later these opacities have disappeared, and the vitreous contains reddish opacities of various sizes.

Even in young subjects, one constantly finds, after a hæmorrhage, minute opacities in the vitreous, even when the visual acuity has become normal.

As regards etiology, probably tuberculosis is most often responsible. We have reported a case in which the reaction to injection of minimal doses of tuberculin was accompanied with fresh hæmorrhages.

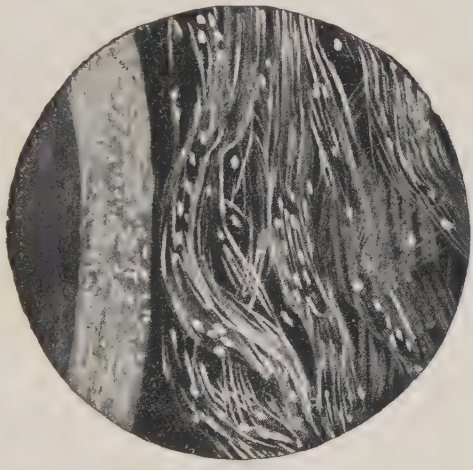

FIG. 43.—Old detachment of the retina. On the left are seen precipitates on the capsule. On the right, in the loosened bundles of the fibres of the vitreous, many opacities in the shape of golden platelets shown in front view and in profile. Magnification about × 30. Figure slightly schematic.

Glaucoma.—Alterations of the vitreous characteristic of this disease have not yet been described. The framework of the vitreous may remain intact even in advanced cases of glaucoma. There are sometimes fine brown opacities. Koeppe accepts a pigmentary disintegration in his "pre-glaucoma." Vogt sees in this dispersion of pigment only a senile change. Observation of the vitreous is impeded by the fact that if the patient presents himself with glaucomatous mydriasis, the cornea is generally too hazy to allow of a satisfactory examination.

It is to be noted that Vogt has observed in some cases of glaucoma an extraordinary sagittal thickening of the lens.

Synchysis scintillans does not give the microscopic picture that the ophthalmoscope would lead one to expect. The opacities have not the form of crystals, but of *quite white rounded agglomerations arranged like a chaplet.* The authors are very emphatic on this point (Koeppe, Vogt, Gallemaerts, Kleefeld and ourselves). Destruction of the framework may be marked, but not so great as in the case of retinal detachment.

The opacities are sometimes perfectly round and always vary in size, measuring on an average 0·05 mm. in diameter.

Detachment of the Retina.—The framework of the vitreous is completely broken up, especially in old cases of myopic detachment. One no longer sees a regular network, but irregular and twisted fibres (*cf.* Fig. 43). These are large, more or less dark, empty spaces. At length there appear large golden or red platelets. At a quite early stage changes in the framework are hardly noticeable and the plaques are absent.

The hypothesis that detachment of the retina is due to the formation of vitreous bands has not been supported by microscopy of the living eye. We never see bands, which might help to bring about detachment of the retina, forming in the framework of the vitreous of a myope.

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Archiv für Ophtalmologie *Ar. f. Opht.*
Archivos de oftalmolgia hispano-americanos *Ar. de oft. hisp.-am.*
British Journal of Ophthalmology *Brit. J. of Opht.*
Klinische Monatsblätter für Augenheilkunde *Kl. Mbl. f. A.*
Revue générale d'ophtalmologie *Rev. gén. d'opht.*
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